



ALPHA-7 NICOTINIC RECEPTOR

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FIELD OF THE INVENTION

The present invention is related to the $\alpha 7$ neuronal nicotinic acetylcholine receptor gene. In particular, the present invention provides the human $\alpha 7$ gene.

BACKGROUND OF THE INVENTION

Schizophrenia is the most common chronic psychotic disorder of humans, affecting approximately one percent of the population worldwide (Eaton, Epidemiol. Rev., 7:105 [1985]). The mean lifetime risk of schizophrenia has been estimated at one percent (Eaton, *supra*). As the onset of disease usually occurs early in life, and results in serious chronic impairment of cognition, behavior, and emotional state, schizophrenia is a major social problem in terms of cost, lost potential and productivity, and family stress. Furthermore, estimates indicate that the mortality of schizophrenic patients is twice that of the general population (Tsuang *et al.*, Arch. Gen. Psychiat., 36:1295 [1979]). The medical care of schizophrenic patients also presents a significant challenge, as the patients are often unable to provide an accurate medical history, and have difficulty complying with medical treatment.

The essential features of schizophrenia are the presence of psychotic symptoms during some phase of the illness, a chronic course, and deterioration in function. However, no combination of signs or symptoms is truly pathognomic of the disease. The DSM-IV criteria for schizophrenia (See, Hyman, "Schizophrenia," in Dale and Federman (eds), *Scientific American Medicine*, New York, New York [1994], 13 VII:1-5), requires a duration of at least six months, and a deterioration in function. Psychotic symptoms typically exhibited by schizophrenia patients include disturbances

in perception, abnormalities in thought content, and abnormalities in the form of thought. Perceptual disturbances typically consist of hallucinations and illusions. The course of schizophrenia is variable, although it is generally characterized by periods with exacerbation of psychotic symptoms, followed by periods of remission. Over a period of years, social and cognitive function usually deteriorates. Suicide attempts and depression are common. As measured by frequency and severity of relapses, continuing symptoms, and overall functioning, approximately 80% of schizophrenics have a poor outcome (Breier *et al.*, Arch. Gen. Psychiat., 48:239 [1991]).

Although family, twin, and adoption studies indicate that schizophrenia has a significant genetic component, these studies also show that the inheritance of schizophrenia is complex, involving an uncertain mode of transmission, incomplete penetrance, and probable genetic heterogeneity (Risch, Genet. Epidemiol., 7:3 [1990]; and Tsuang, Brit. J. Psychiat., 163:299 [1993]). Linkage studies using schizophrenia and related psychiatric cases as phenotypes have found possible loci for schizophrenia at various chromosomal sites in subsets of families (Pulver *et al.*, Am. J. Med. Genet., 54:44 [1994]; Coon *et al.*, Am. J. Med. Genet., 54:12 [1994]; Wang *et al.*, Nature Genet., 10:41 [1995]; and Silverman *et al.*, Am. J. Med. Genet., 67:162 [1996]). However, the findings do not account completely for the inheritance of schizophrenia, nor do they delineate which aspects of this multifactorial illness might be influenced by a specific locus.

A variety of psychiatric disorders may mimic schizophrenia and the symptoms of many disorders are similar. Thus, diagnosis has been based on the course of illness (for example, acute onset and episodic course in mania, compared with an insidious onset and chronic course in schizophrenia). In addition to schizophrenia, psychotic symptoms may also occur as a result of metabolic disturbances, structural brain lesions, other medical conditions, or drug toxicity. Thus, the differential diagnosis of schizophrenia must take into consideration such medical conditions as central nervous system neoplasm, hyperviscosity syndromes (*i.e.*, due to hematologic malignancy), paraneoplastic syndromes, anoxia and postanoxic encephalopathy, hypertensive

encephalopathy, AIDS encephalopathy, encephalitis, meningitis, brain abscess, Lyme disease, neurosyphilis, acute intermittent porphyria, Addison's disease, Cushing's disease, hepatic encephalopathy, hypocalcemia, hypercalcemia, hypoglycemia, hypothyroidism, hyperthyroidism, Alzheimer's disease, complex partial seizures, Huntington's disease, multiple sclerosis, stroke, Wilson's disease, folic acid deficiency, pellagra, vitamin B₁₂ deficiency, and lupus cerebritis. Some drugs, such as alcohol, high-dose cocaine, high-dose amphetamines, marijuana, phencyclidine (PCP), hallucinogens, sedative-hypnotics, meperidine, non-steroidal anti-inflammatory drugs, pentazocine and other opiate mixed agonist-antagonists, anti-tuberculosis drugs (*e.g.*, cycloserine, isoniazid, rifampin), other antimicrobials, anticholinergic anti-parkinsonians, anti-histamines (*e.g.*, diphenhydramine), atropine and derivatives, cyclic antidepressants, low-potency antipsychotic drugs (*e.g.*, thioridazine and clozapine), meclizine, scopolamine, anti-arrhythmic (*e.g.*, amiodarone, digitalis, and procainamide), captopril, amantadine, D₂ dopamine receptor antagonists (*e.g.*, bromocriptine, and pergolide), levodopa, estrogens, testosterone, glucocorticoids and adrenocorticotrophic hormone (ACTH), thyroid replacement overdose, cimetidine, ranitidine, dextroamphetamine, methylphenidate, and over-the-counter decongestants (*e.g.*, pseudoephedrine), diet pills, and pep pills, are commonly associated with psychotic symptoms.

Treatment of schizophrenic patients usually involves the use of anti-psychotic drugs (*e.g.*, haloperidol, haloperidol-like drugs, and clozapine), maintenance of a safe, predictable environment, and supportive psychotherapy to improve social and coping skills of patients. Stress reduction also appears to prevent relapses. While these drugs are useful in treating the symptoms of schizophrenia, there are also problems associated with their use. For example, the use of clozapine is complicated by the idiosyncratic occurrence of agranulocytosis, necessitating weekly monitoring of the white blood cell counts of patients taking this drug (*See, Hyman, supra*).

Despite advances in treatment and diagnostic methods, there remains a need for methods to diagnose and treat schizophrenic patients. Indeed, methods to diagnose and

screen large populations for genetic component(s) associated with schizophrenia, as well as other psychoses are needed in order to provide reliable diagnoses that are not dependent upon the multifactorial criteria presently in use. Improved methods of treatment are also needed, including drugs and other therapeutics that do not have the side effects and other undesirable properties associated with the currently used drugs.

SUMMARY OF THE INVENTION

The present invention is related to the $\alpha 7$ neuronal nicotinic acetylcholine receptor gene. In particular, the present invention provides the human $\alpha 7$ gene.

In one embodiment, the present invention provides an isolated nucleotide sequence encoding at least a portion of the human alpha-7 nicotinic receptor, wherein the sequence is selected from the group consisting of SEQ ID NOS:84-103. In an alternative embodiment, the present invention provides an isolated peptide sequence encoded by the isolated nucleotide sequence, wherein the nucleotide sequence is selected from the group consisting of SEQ ID NOS:84-103. In another embodiment, the nucleotide sequence further comprises 5' and 3' flanking regions. In yet another embodiment, the nucleotide sequence further comprises intervening regions. In a further embodiment, the present invention provides an isolated polynucleotide sequence comprising a combination of two or more nucleotide sequences, wherein the nucleotide sequences are selected from the group consisting of SEQ ID NOS:84-103. It is not intended that the combination comprise any particular number or order of these nucleotide sequences, nor is it intended that the combination be limited to the inclusion of any particular nucleotide sequence.

In another embodiment, the present invention provides vectors comprising a nucleotide sequence, wherein the nucleotide sequence comprises at least one nucleotide sequence selected from the group consisting of SEQ ID NOS:84-103. In another embodiment, the present invention provides a host cell transformed with a vector comprising a nucleotide sequence, wherein the nucleotide sequence comprises at least one nucleotide sequence selected from the group consisting of SEQ ID NOS:84-103.

In one embodiment, the host cell is selected from the group consisting of bacteria, yeast, amphibian, and mammalian cells. In one preferred embodiment, the host cell is a human cell. In an alternative preferred embodiment, the the host cell is a cell line, while in another preferred embodiment, the host cell is contained within an animal.

5 The present invention also provides a first polynucleotide sequence comprising at least fifteen nucleotides, which hybridizes under stringent conditions to at least a portion of a second polynucleotide sequence, wherein the second polynucleotide sequence is selected from the polynucleotide sequences selected from the group consisting of SEQ ID NOS:84-103..

10 The present invention also provides methods for detection of a polynucleotide encoding alpha-7 protein in a biological sample suspected of containing the polynucleotide encoding alpha-7, comprising the step of hybridizing at least a portion of a polynucleotide sequence selected from the group consisting of SEQ ID NOS:9-11, and 84-103, to nucleic acid of the biological sample to produce an hybridization
15 complex. In one embodiment, the method further comprises the step of detecting the hybridization complex, wherein the presence of the complex correlates with the presence of a polynucleotide encoding alpha-7 in the biological sample. In another embodiment, the biological sample is a sample selected from the group consisting of brain tissue and blood. In one preferred embodiment, the biological sample is from a
20 human. In yet another embodiment, the human is suspected of suffering from a condition selected from the group consisting of schizophrenia, small cell lung carcinoma, breast cancer, and nicotine-dependent illness. In yet another preferred embodiment of the method, the nucleic acid of the biological sample is amplified by the polymerase chain reaction prior to hybridization.

25 The present invention also provides methods for amplification of nucleic acid from a sample suspected of containing nucleic acid encoding alpha-7, comprising the steps of: providing a test sample suspected of containing amplifiable nucleic acid encoding alpha-7; isolating the amplifiable nucleic acid from the test sample; combining the amplifiable nucleic acid with amplification reagents, and at least two
30 primers selected from the group consisting of primers having the nucleic acid sequence

set forth in SEQ ID NOS:1-8, and 12-83 to form a reaction mixture; and combining the reaction mixture with an amplification enzyme under conditions wherein the amplifiable nucleic acid is amplified to form amplification product. In one embodiment, the method further comprises the step of detecting the amplification product. In an alternative embodiment, the detecting is accomplished by hybridization of the amplification product with a probe having the nucleic acid sequence is selected from group of the sequences set forth in SEQ ID NO:9-11. In one preferred embodiment, the test sample is a sample selected from the group consisting of brain tissue and blood. In an alternative preferred embodiment, the test sample is from a human. In yet another embodiment, the human is suspected of suffering from a condition selected from the group consisting of schizophrenia, small cell lung carcinoma, breast cancer, and nicotine-dependent illness.

The present invention also provides methods for amplification of nucleic acid from a sample suspected of containing nucleic acid encoding alpha-7 comprising the steps of: providing a test sample suspected of containing amplifiable nucleic acid encoding alpha-7; isolating the amplifiable nucleic acid from the test sample; combining the amplifiable nucleic acid with amplification reagents, and a first primer set comprising at least two primers selected from the group consisting of the sequences set forth in SEQ ID NOS: 65-70, to form a first reaction mixture; combining the reaction mixture with an amplification enzyme under conditions wherein the amplifiable nucleic acid is amplified to form a first amplification product; combining the first reaction mixture with amplification reagents, and a second primer set comprising at least two primers selected from the group consisting of the sequences set forth in SEQ ID NOS:57-59, 61, 63, 67, and 73-75, to form a second reaction mixture; combining the second reaction mixture with an amplification enzyme under conditions wherein the amplifiable nucleic acid is amplified to form a second amplification product; and detecting the first or second amplification product.

In one preferred embodiment of the method, the detecting comprises hybridizing the amplification product with a probe having a nucleic acid sequence selected from the group consisting of the nucleic acid sequence set forth in SEQ ID

NOS:9-11. In yet another embodiment, the test sample is a sample selected from the group consisting of brain tissue and blood. In another preferred embodiment of the method, the test sample is from a human. In a further embodiment, the is suspected of suffering from a condition selected from the group consisting of schizophrenia, small cell lung carcinoma, breast cancer, and nicotine-dependent illness.

The present invention also provides methods for producing anti- $\alpha 7$ antibodies (including, but not limited to antibodies directed against peptides comprising $\alpha 7$), comprising, exposing an animal having immunocompetent cells to an immunogen comprising at least an antigenic portion of $\alpha 7$ protein, under conditions such that immunocompetent cells produce antibodies directed against the portion of $\alpha 7$. In preferred embodiments, the $\alpha 7$ peptide or protein is human $\alpha 7$. In one embodiment, the method further comprises the step of harvesting the antibodies. In an alternative embodiment, the method comprises the step of fusing the immunocompetent cells with an immortal cell line under conditions such that an hybridoma is produced. In other embodiments, the immunogen comprises a fusion protein.

The present invention also provides methods for detecting abnormal $\alpha 7$ expression comprising the steps of: a) providing a sample suspected of containing test $\alpha 7$; and a control containing a quantitated $\alpha 7$; and b) comparing the test $\alpha 7$ in the sample with the quantitated $\alpha 7$ in the control to determine the relative concentration of the test $\alpha 7$ in the sample. In one embodiment of the method, the control contains a higher concentration of quantitated $\alpha 7$ than the concentration of the test $\alpha 7$ in the sample. Thus, the methods are capable of identifying samples (*e.g.*, patient samples) with reduced $\alpha 7$ protein. The methods also provide means to detect samples that contain a normal amount of $\alpha 7$ protein. In addition, the methods may be conducted using any suitable means to determine the relative concentration of $\alpha 7$ in the test and control samples, including but not limited to the means selected from the group consisting of Western blot analysis, Northern blot analysis, Southern blot analysis, denaturing polyacrylamide gel electrophoresis, reverse transcriptase-coupled polymerase chain reaction, enzyme-linked immunosorbent assay, radioimmunoassay, and fluorescent immunoassay. Thus, the methods may be conducted to determine the

presence of $\alpha 7$ in the genome of the animal source of the test sample, or the expression of $\alpha 7$ (mRNA or protein), as well as detect the presence of abnormal or mutated $\alpha 7$ proteins or gene sequences in the test samples.

5 In one preferred embodiment, the presence of $\alpha 7$ is detected by immunochemical analysis. For example, the immunochemical analysis can comprise detecting binding of an antibody specific for an epitope of $\alpha 7$. In another preferred embodiment of the method, the antibody comprises polyclonal antibodies, while in another preferred embodiment, the antibody is comprises monoclonal antibodies.

10 The antibodies used in the methods invention may be prepared using various immunogens. In one embodiment, the immunogen is a human $\alpha 7$ peptide to generate antibodies that recognize human $\alpha 7$. Such antibodies include, but are not limited to polyclonal, monoclonal, chimeric, single chain, Fab fragments, and an Fab expression library.

15 Various procedures known in the art may be used for the production of polyclonal antibodies to $\alpha 7$ (e.g., human $\alpha 7$). For the production of antibody, various host animals can be immunized by injection with the peptide corresponding to the human $\alpha 7$ epitope including but not limited to rabbits, mice, rats, sheep, goats, etc. In a preferred embodiment, the peptide is conjugated to an immunogenic carrier (e.g., diphtheria toxoid, bovine serum albumin (BSA), or keyhole limpet hemocyanin [KLH]).
20 Various adjuvants may be used to increase the immunological response, depending on the host species, including but not limited to Freund's (complete and incomplete), mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanins, dinitrophenol, and potentially useful human adjuvants such as BCG
25 (Bacille Calmette-Guerin) and *Corynebacterium parvum*.

For preparation of monoclonal antibodies directed against $\alpha 7$, any technique that provides for the production of antibody molecules by continuous cell lines in culture may be used (See, e.g., Harlow and Lane, *Antibodies: A Laboratory Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY). These include but

are not limited to the hybridoma technique originally developed by Köhler and Milstein (Köhler and Milstein, *Nature* 256:495-497 [1975]), as well as the trioma technique, the human B-cell hybridoma technique (*See e.g.*, Kozbor *et al.* *Immunol. Today* 4:72 [1983]), and the EBV-hybridoma technique to produce human monoclonal antibodies (Cole *et al.*, in *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, Inc., pp. 77-96 [1985]).

In an additional embodiment of the invention, monoclonal antibodies can be produced in germ-free animals utilizing recent technology (*See e.g.*, PCT/US90/02545). According to the invention, human antibodies may be used and can be obtained by using human hybridomas (Cote *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* 80:2026-2030 [1983]), or by transforming human B cells with EBV virus *in vitro* (Cole *et al.*, in *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, pp. 77-96 [1985]).

According to the invention, techniques described for the production of single chain antibodies (U.S. Patent 4,946,778; herein incorporated by reference) can be adapted to produce $\alpha 7$ single chain antibodies. An additional embodiment of the invention utilizes the techniques described for the construction of Fab expression libraries (Huse *et al.*, *Science* 246:1275-1281 [1989]) to allow rapid and easy identification of monoclonal Fab fragments with the desired specificity for $\alpha 7$.

Antibody fragments which contain the idiotype (antigen binding region) of the antibody molecule can be generated by known techniques. For example, such fragments include but are not limited to: the F(ab')₂ fragment which can be produced by pepsin digestion of the antibody molecule; the Fab' fragments which can be generated by reducing the disulfide bridges of the F(ab')₂ fragment, and the Fab fragments which can be generated by treating the antibody molecule with papain and a reducing agent.

In the production of antibodies, screening for the desired antibody can be accomplished by techniques known in the art (*e.g.*, radioimmunoassay, ELISA (enzyme-linked immunosorbent assay), "sandwich" immunoassays, immunoradiometric

assays, gel diffusion precipitin reactions, immunodiffusion assays, *in situ* immunoassays (using colloidal gold, enzyme or radioisotope labels, for example), Western Blots, precipitation reactions, agglutination assays (*e.g.*, gel agglutination assays, hemagglutination assays, etc.), complement fixation assays, immunofluorescence assays, protein A assays, and immunoelectrophoresis assays, etc.

In one embodiment, antibody binding is detected by detecting a label on the primary antibody. In another embodiment, the primary antibody is detected by detecting binding of a secondary antibody or reagent to the primary antibody. In a further embodiment, the secondary antibody is labeled. Many means are known in the art for detecting binding in an immunoassay and are within the scope of the present invention. (As is well known in the art, the immunogenic peptide should be provided free of the carrier molecule used in any immunization protocol. For example, if the peptide was conjugated to KLH, it may be conjugated to BSA, or used directly, in a screening assay.)

The foregoing antibodies can be used in methods known in the art relating to the localization and structure of $\alpha 7$ (*e.g.*, for Western blotting), measuring levels thereof in appropriate biological samples, etc. The antibodies can be used to detect $\alpha 7$ in a biological sample from an individual. The biological sample can be a biological fluid, such as but not limited to, blood, serum, plasma, cerebrospinal fluid (CSF), and the like, containing cells. In particular, $\alpha 7$ can be detected from cellular sources, such as, but not limited to, brain tissue.

The biological samples can then be tested directly for the presence of $\alpha 7$ using an appropriate strategy (*e.g.*, ELISA or radioimmunoassay) and format (*e.g.*, microwells, dipstick [*e.g.*, as described in International Patent Publication WO 93/03367], etc.). Alternatively, proteins in the sample can be size separated (*e.g.*, by polyacrylamide gel electrophoresis (PAGE), in the presence or not of sodium dodecyl sulfate (SDS), and the presence of $\alpha 7$ detected by immunoblotting (Western blotting)). Immunoblotting techniques are generally more effective with antibodies generated

against a peptide corresponding to an epitope of a protein, and hence, are particularly suited to the present invention.

5 The foregoing explanations of particular assay systems are presented herein for purposes of illustration only, in fulfillment of the duty to present an enabling disclosure of the invention. It is to be understood that the present invention contemplates a variety of immunochemical assay protocols within its spirit and scope.

10 In some preferred aspects, genomic DNA or mRNA is amplified by PCR, and the amplified DNA is tested for the presence of mutation(s). PCR amplification is well known in the art (Cameron *et al.*, Science 257:383-387 [1992]; Saksela *et al.*, 1994, Proc. Natl. Acad. Sci. U.S.A., 91:1104-1108 [1994]). For example, mRNA can be detected by reverse transcriptase-initiated PCR (*See, e.g.*, Saksela *et al.*, J. Virol., 67:7423-27 [1993]). PCR can be carried out (*e.g.*, by use of a Perkin-Elmer Cetus thermal cycler and *Taq* polymerase (*e.g.*, Gene Amp®, Boehringer Mannheim). The amplified PCR products can be analyzed by immobilization on membranes and
15 hybridization with specific oligonucleotide probes, or by treatment with specific endonucleases and analysis of the products by gel electrophoresis. Labeling of the cleaved PCR products can be accomplished by incorporation of radiolabeled nucleotides, endlabeling (*e.g.*, with ³²P-ATP), or by staining with ethidium bromide.

20 The present invention also provides methods and compositions suitable for gene therapy for individuals deficient in $\alpha 7$ expression, production, or function. Viral vectors commonly used for *in vivo* or *ex vivo* targeting and therapy procedures are DNA-based vectors and retroviral vectors. Methods for constructing and using viral vectors are known in the art (*See, e.g.*, Miller and Rosman, BioTechn., 7:980-990 [1992]). Preferably, the viral vectors are replication defective, that is, they are unable
25 to replicate autonomously in the target cell. In general, the genome of the replication defective viral vectors which are used within the scope of the present invention lack at least one region which is necessary for the replication of the virus in the infected cell. These regions can either be eliminated (in whole or in part), be rendered non-functional by any technique known to a person skilled in the art. These

techniques include the total removal, substitution (by other sequences, in particular by the inserted nucleic acid), partial deletion or addition of one or more bases to an essential (for replication) region. Such techniques may be performed *in vitro* (i.e., on the isolated DNA) or *in situ*, using the techniques of genetic manipulation or by treatment with mutagenic agents.

Preferably, the replication defective virus retains the sequences of its genome which are necessary for encapsidating the viral particles. DNA viral vectors include an attenuated or defective DNA virus, including, but not limited to, herpes simplex virus (HSV), papillomavirus, Epstein Barr virus (EBV), adenovirus, adeno-associated virus (AAV), and the like. Defective viruses, which entirely or almost entirely lack viral genes, are preferred, as defective virus is not infective after introduction into a cell. Use of defective viral vectors allows for administration to cells in a specific, localized area, without concern that the vector can infect other cells. Thus, a specific tissue can be specifically targeted. Examples of particular vectors include, but are not limited to, a defective herpes virus 1 (HSV1) vector (Kaplitt *et al.*, Mol. Cell. Neurosci., 2:320-330 [1991]), defective herpes virus vector lacking a glycoprotein L gene (*See e.g.*, Patent Publication RD 371005 A), or other defective herpes virus vectors (*See e.g.*, International Patent Publication No. WO 94/21807; and International Patent Publication No. WO 92/05263); an attenuated adenovirus vector, such as the vector described by Stratford-Perricaudet *et al.* (J. Clin. Invest., 90:626-630 [1992]; *See also*, La Salle *et al.*, Science 259:988-990 [1993]); and a defective adeno-associated virus vector (Samulski *et al.*, J. Virol., 61:3096-3101 [1987]; Samulski *et al.*, J. Virol. 63:3822-3828 [1989]; and Lebkowski *et al.*, Mol. Cell. Biol., 8:3988-3996 [1988]).

Preferably, for *in vivo* administration, an appropriate immunosuppressive treatment is employed in conjunction with the viral vector (*e.g.*, adenovirus vector), to avoid immuno-deactivation of the viral vector and transfected cells. For example, immunosuppressive cytokines, such as interleukin-12 (IL-12), interferon-gamma (IFN- γ), or anti-CD4 antibody, can be administered to block humoral

r cellular immune responses to the viral vectors. In addition, it is advantageous to employ a viral vector that is engineered to express a minimal number of antigens.

In a preferred embodiment, the vector is an adenovirus vector. Adenoviruses are eukaryotic DNA viruses that can be modified to efficiently deliver a nucleic acid of the invention to a variety of cell types. Various serotypes of adenovirus exist. Of these serotypes, preference is given, within the scope of the present invention, to type 2 or type 5 human adenoviruses (Ad 2 or Ad 5), or adenoviruses of animal origin (See, WO94/26914). Those adenoviruses of animal origin which can be used within the scope of the present invention include adenoviruses of canine, bovine, murine (e.g., Mav1, Beard *et al.*, Virol., 75-81 [1990]), ovine, porcine, avian, and simian (e.g., SAV) origin. Preferably, the adenovirus of animal origin is a canine adenovirus, more preferably a CAV2 adenovirus (e.g., Manhattan or A26/61 strain (ATCC VR-800), for example).

In another embodiment the gene can be introduced in a retroviral vector (e.g., as described in U.S. Patent Nos. 5,399,346, 4,650,764, 4,980,289 and 5,124,263; all of which are herein incorporated by reference; Mann *et al.*, Cell 33:153 [1983]; Markowitz *et al.*, J. Virol., 62:1120 [1988]; PCT/US95/14575; EP 453242; EP178220; Bernstein *et al.* Genet. Eng., 7:235 [1985]; McCormick, BioTechnol., 3:689 [1985]; International Patent Publication No. WO 95/07358; and Kuo *et al.*, Blood 82:845 [1993]). The retroviruses are integrating viruses which infect dividing cells. The retrovirus genome includes two LTRs, an encapsidation sequence and three coding regions (*gag*, *pol* and *env*). In recombinant retroviral vectors, the *gag*, *pol* and *env* genes are generally deleted, in whole or in part, and replaced with a heterologous nucleic acid sequence of interest. These vectors can be constructed from different types of retrovirus, such as, HIV, MoMuLV ("murine Moloney leukaemia virus" MSV ("murine Moloney sarcoma virus"), HaSV ("Harvey sarcoma virus"); SNV ("spleen necrosis virus"); RSV ("Rous sarcoma virus") and Friend virus. Defective retroviral vectors are disclosed in WO95/02697.

In general, in order to construct recombinant retroviruses containing a nucleic acid sequence, a plasmid is constructed which contains the LTRs, the encapsidation sequence and the coding sequence. This construct is used to transfect a packaging cell line, which cell line is able to supply in trans the retroviral functions which are
5 deficient in the plasmid. In general, the packaging cell lines are thus able to express the *gag*, *pol* and *env* genes. Such packaging cell lines have been described in the prior art, in particular the cell line PA317 (US Patent No. 4,861,719, herein incorporated by reference); the PsiCRIP cell line (*See*, WO90/02806), and the GP+envAm-12 cell line (*See*, WO89/07150). In addition, the recombinant retroviral vectors can contain
10 modifications within the LTRs for suppressing transcriptional activity as well as extensive encapsidation sequences which may include a part of the *gag* gene (Bender *et al.*, J. Virol., 61:1639 [1987]). Recombinant retroviral vectors are purified by standard techniques known to those having ordinary skill in the art.

Alternatively, the vector can be introduced *in vivo* by lipofection. For the past
15 decade, there has been increasing use of liposomes for encapsulation and transfection of nucleic acids *in vitro*. Synthetic cationic lipids designed to limit the difficulties and dangers encountered with liposome mediated transfection can be used to prepare liposomes for *in vivo* transfection of a gene encoding a marker (Felgner *et al.*, Proc. Natl. Acad. Sci. U.S.A., 84:7413-7417 [1987]; *See also*, Mackey, *et al.*, Proc. Natl.
20 Acad. Sci. U.S.A., 85:8027-8031 [1988]; Ulmer *et al.*, Science 259:1745-1748 [1993]). The use of cationic lipids may promote encapsulation of negatively charged nucleic acids, and also promote fusion with negatively charged cell membranes (Felgner and Ringold, Science 337:387-388 [1989]). Particularly useful lipid compounds and compositions for transfer of nucleic acids are described in International Patent
25 Publications WO95/18863 and WO96/17823, and in U.S. Patent No. 5,459,127, herein incorporated by reference.

Other molecules are also useful for facilitating transfection of a nucleic acid *in vivo*, such as a cationic oligopeptide (*e.g.*, International Patent Publication WO95/21931), peptides derived from DNA binding proteins (*e.g.*, International Patent

Publication WO96/25508), or a cationic polymer (*e.g.*, International Patent Publication WO95/21931).

It is also possible to introduce the vector *in vivo* as a naked DNA plasmid. Methods for formulating and administering naked DNA to mammalian muscle tissue are disclosed in US Patent Nos. 5,580,859 and 5,589,466, both of which are herein incorporated by reference.

DNA vectors for gene therapy can be introduced into the desired host cells by methods known in the art, including but not limited to transfection, electroporation, microinjection, transduction, cell fusion, DEAE dextran, calcium phosphate precipitation, use of a gene gun, or use of a DNA vector transporter (*See e.g.*, Wu *et al.*, J. Biol. Chem., 267:963-967 [1992]; Wu and Wu, J. Biol. Chem., 263:14621-14624 [1988]; Williams *et al.*, Proc. Natl. Acad. Sci. U.S.A., 88:2726-2730 [1991]). Receptor-mediated DNA delivery approaches can also be used (Curiel *et al.*, Hum. Gene Ther., 3:147-154 [1992]; Wu and Wu, J. Biol. Chem., 262:4429-4432 [1987]).

The present invention also provides methods and compositions for the production of *in vitro* cell cultures that express wild-type or mutated human $\alpha 7$, as well as transgenic animals capable of expressing wild-type or mutated human $\alpha 7$. For example, the genomic $\alpha 7$ clone can be expressed in mammalian cells (*e.g.*, cell lines, including but not limited to mammalian kidney cells, such as HEK). It is also contemplated that in some embodiments, the cells and animals also express other foreign genes in conjunction with the introduced $\alpha 7$.

The present invention also provides methods for producing non-human transgenic animals, comprising the steps of a) introducing into an embryonal cell of a non-human animal a polynucleotide sequence encoding an $\alpha 7$ protein; b) transplanting the transgenic embryonal target cell formed thereby into a recipient female parent; and c) identifying at least one offspring containing the transgene wherein the $\alpha 7$ mRNA is overexpressed in the tissue of the offspring. In one preferred embodiment, the $\alpha 7$ mRNA is human $\alpha 7$ mRNA. In an alternative

embodiment, the polynucleotide sequence encoding an $\alpha 7$ protein comprises a yeast artificial chromosome, while in another embodiment, the polynucleotide sequence encoding an $\alpha 7$ is a bacterial artificial chromosome, and in yet another embodiment, the polynucleotide sequence encoding an $\alpha 7$ protein is a P1 artificial chromosome. In
5 a further embodiment, the non-human animal is a member of the Order Rodentia. In a preferred embodiment, the non-human animal is a mouse.

DESCRIPTION OF THE FIGURES

Figure 1 is a table showing the exon-intron boundary sequences of the human $\alpha 7$ nAChR subunit gene (SEQ ID NOS:84-93).

10 Figure 2 is a table showing the sequence variants identified in full-length and duplicated genomic clones.

Figure 3 is a table showing an expression analysis of sequence variants.

Figure 4 shows the nucleotide sequence of the region 5' of the human $\alpha 7$ nAChR subunit gene (SEQ ID NO:94).

15 Figure 5 shows the genomic contig of clones positive for $\alpha 7$ nAChR gene sequences and surrounding loci.

Figure 6 shows the sequence of RACE clone (SEQ ID NOS:95-100).

Figure 7 provides a map of the full-length $\alpha 7$ nAChR gene. Panel A shows a physical map of the region and the structure of the full-length $\alpha 7$ nAChR gene. Panel
20 B shows the structure of alternatively spliced transcripts.

Figure 8 shows the DNA sequence of the human $\alpha 7$ neuronal nicotinic receptor promoter (SEQ ID NO:101).

Figure 9 shows the DNA sequence of the alternatively spliced human $\alpha 7$ neuronal nicotinic receptor RACE product A/C/D (SEQ ID NO:102).

25 Figure 10 shows the DNA sequence of the alternatively spliced human $\alpha 7$ neuronal nicotinic receptor RACE product A/B/C/D (SEQ ID NO:103).

DESCRIPTION OF THE INVENTION

As the current methods have been unsuccessful in providing needed information regarding the genetics of schizophrenia, an alternative strategy for genetic studies of complex diseases involving the use of a specific neurobiological characteristic of the illness (*e.g.*, as an additional phenotype more closely reflecting the effect of a single genetic alteration), was used during the development of the present invention. Such information is needed in order to provide diagnostic and treatment methods, as well as animal models for schizophrenia, as well as other psychoses. It is contemplated that such a trait is part of the inherited diathesis of the illness, which produces schizophrenia in combination with other pathogenic elements.

The present invention provides genetic information (*i.e.*, sequences, including sequence location and information for intron/exon boundaries) for the $\alpha 7$ nicotinic receptor, as well as methods to assess the function of this receptor in normal, as well as schizophrenic individuals. The present invention also provides methods and compositions for analyzing samples from patients suspected of suffering from diverse conditions, including epilepsy (*e.g.*, juvenile myoclonic epilepsy), small cell lung carcinoma and other nicotine-dependent diseases, Prader-Willi, Angelman's syndrome, and other genetic disorders, etc. Indeed, it is not intended that the present invention be limited to schizophrenia.

The following description of the present invention is arranged in four sections, including (I) Inhibition of the P50 Auditory Response; (II) Neuronal Nicotinic Receptor Subunit Family; (III) Treatment and Diagnosis of Schizophrenia and Other Psychoses; and (IV) Transgenic Animals.

I. Inhibition of the P50 Auditory Response

Various psychophysiological paradigms demonstrate altered brain functions in schizophrenic patients and their relatives that might reflect inherited traits (*See e.g.*, Sham *et al.*, *Psychiat. Genet.*, 4:29 [1994]; De Amicis *et al.*, *J. Nerv. Ment. Dis.*, 174:177 [1986]; Holzman *et al.*, *Arch. Gen. Psychiat.*, 45:641 [1988]; and Braff *et al.*,

Arch. Gen. Psychiat., 49:206 [1992]). Basic deficits in the regulation of response to sensory stimuli may underlie patients' more apparent symptoms such as hallucinations and delusions. In addition to hearing voices, patients often attend to apparently extraneous stimuli in their surroundings that normal individuals generally ignore. Such symptoms suggested that neuronal mechanisms responsible for the filtering or gating of sensory input to higher brain centers are deficient. One method developed for examining such neuronal mechanisms compares the responses to first and second of paired stimuli. The first stimulus elicits an excitatory response that also activates inhibitory mechanisms, which then diminish the excitatory response to the second stimulus. The ratio of the amplitude of the second response to the first is inversely related to the strength of inhibition.

During the development of the present invention, this method was used to study the response to auditory stimuli in schizophrenia, using an electrically positive evoked potential occurring 50 ms after an auditory stimulus (P50). Inhibition of the P50 response to a second identical stimulus, presented 500 ms after the first, has been reported to be diminished in schizophrenics (Adler *et al.*, Biol. Psychiat., 17:639 [1982]; Boutros and Overall, Clin. Electroencephalog., 22:20 [1991]; Erwin *et al.*, Biol. Psychiat., 30, 430 [1991]; and Judd *et al.*, Am. J. Psychiat., 149:488 [1992]). This diminished inhibition, measured as an elevation in the ratio of P50 amplitudes, has been correlated with schizophrenics' decreased performance in a neuropsychological measure of sustained attention, as well as diminished performance in a word recognition task (Cullum *et al.*, Schizophrenia Res., 10:131 [1993]; and Vinogradova *et al.*, Biol. Psychiat., 39: 821 [1996]).

In the development of the present invention, inhibition of the P50 response was measured in animal and related clinical investigations, to identify neurobiological mechanisms related to genes of interest, as well as a phenotype for linkage analysis to identify chromosomal areas containing genes responsible for the abnormality in schizophrenics.

The neurobiological inhibition of human P50 to repeated auditory stimuli was initially investigated using an auditory evoked potential recorded from the rat as a model. Both the human and rat potentials show similar decreased responses to repeated auditory stimuli (Adler *et al.*, Biol. Psychiat., 21:787 [1986]). Neuronal recordings identified the pyramidal neurons of the hippocampus as a major source of the rat evoked potential. These pyramidal neurons have a decremented response to repeated auditory stimuli that parallels the decrement in the evoked potential (Bickford-Wimer *et al.*, Biol. Psychiat., 27:183 [1990]). The decrement is lost after transection of the fimbria-fornix, a fiber tract that includes afferents to the hippocampus from cholinergic neurons in the basal forebrain (Vinogradova, in *The Hippocampus 2: Neurophysiology and Behavior*, Issacson and Pribram (eds), Plenum Press, New York, NY, [1975], pp 3-69).

However, nicotine has been found to normalize inhibition of response in the fimbria-fornix lesioned animals (*See e.g.*, Bickford and Wear, Brain Res., 705:235 [1995]). Studies with pharmacological antagonists in unlesioned animals indicate that a specific subset of nicotinic cholinergic receptors is involved in the inhibitory mechanism. The inhibition is selectively blocked by the snake toxin α -bungarotoxin (Luntz-Leybman *et al.*, Brain Res., 587:130 [1992]), suggesting that the receptor contains the $\alpha 7$ nicotinic cholinergic receptor subunit, as it is the only known nicotinic receptor subunit in the mammalian brain sensitive to this toxin (Couturier *et al.*, Neuron 5:847-856 [1990]; Schoepfer *et al.*, Neuron 5:35 [1990]). Neither scopolamine, mecamylamine, nor κ -bungarotoxin (*i.e.*, antagonists of other types of cholinergic receptors), blocked the inhibition. Receptor autoradiography using [125 I]- α -bungarotoxin showed the most intense binding to non-pyramidal hippocampal neurons containing the inhibitory neurotransmitter γ -aminobutyric acid (Freedman *et al.*, J. Neurosci., 13:1965 [1993]). This labeling was consistent with physiological evidence that cholinergic synapses activate interneurons, which inhibit the pyramidal neuron response to the second stimulus (*See e.g.*, Miller and Freedman, Neurosci., 69:371-381 [1995]; and Hershman *et al.*, Neurosci. Lett., 190:133 [1995]).

There are several areas of apparent concordance between these findings in rats and P50 inhibition in humans. First, P50 has been recorded from the human hippocampus (Goff *et al.*, Prog. Clin. Neurophysiol., 7:126 [1980]; and Makela *et al.*, Electroencephalogr. Clin. Neurophysiol., 92:414 [1994]), and human hippocampal neurons have rapidly decreasing responses to auditory stimuli, similar to those observed with rat hippocampal neurons (Wilson *et al.*, Exp. Neurol., 84:74 [1984]). Second, nicotine in high doses transiently normalizes the abnormality in P50 inhibition in schizophrenics and in their relatives, much as it normalizes inhibition in rats after fimbria-fornix lesions (Bickford and Wear, *supra*; Adler *et al.*, Biol. Psychiatry 32:607[1992]; and Adler *et al.*, Am. J. Psychiat., 150:1856 [1993]). However, the effect of nicotine on P50 inhibition in relatives of schizophrenics is not blocked by mecamylamine, which blocks all known nicotinic receptors in human brain, except the $\alpha 7$ nicotinic receptor (Freedman *et al.*, Harvard Rev. Psychiat., 2:179 [1994]). *In situ* hybridization has shown that $\alpha 7$ nicotinic receptor mRNA is expressed in human hippocampal neurons (Freedman *et al.*, Harvard Rev. Psychiat., 2:179 [1994]). Some of the non-pyramidal neurons of the human hippocampus were intensely labeled by α -bungarotoxin, as was also observed with rats.

A preliminary study showed that α -bungarotoxin labeling was decreased in post mortem hippocampus from eight schizophrenics (Freedman *et al.*, Biol. Psychiatry, 38:22 [1995]). In addition, schizophrenic patients are particularly heavy tobacco smokers, even when compared to other psychiatric patients (deLeon *et al.*, Am. J. Psychiat., 152:453 [1995]; and Hamera *et al.*, J. Nerv. Mental Dis., 183: 559 [1995]). This heavy nicotine use may reflect an attempt at self medication of an endogenous neuronal deficit (Goff *et al.*, Am. J. Psychiat., 149:1189 [1992]). However, nicotine's efficacy as an anti-psychotic is limited, due to rapid desensitization and cardiovascular toxicity.

In parallel with these biological studies in human and animals, the P50 evoked potential abnormality was also investigated as a phenotype for genetic linkage analysis. A genome-wide scan was initiated, independent of any candidate gene hypothesis, in

nine multiplex schizophrenic pedigrees, which were also phenotyped with P50 recordings. The deficit in inhibition of the P50 response in these and other schizophrenic families is generally found in one of the parents and half the siblings, including the schizophrenic probands (Siegel *et al.*, Arch. Gen. Psychiat., 41:607-612 [1984]). Although elevated P50 ratios are significantly associated with the apparent genetic risk for schizophrenia, many individuals in the pedigrees who have the deficit are clinically unaffected (Waldo *et al.*, Psychiat. Res., 39:257 [1991]). In this respect, the distribution of the trait resembles several other neurobiological abnormalities in schizophrenics and their relatives, such as deficits in smooth pursuit eye movements and reaction time (De Amicis *et al.*, J. Nerv. Ment. Dis., 174:177 [1986]; and Holzman *et al.* Arch. Gen. Psychiat., 45:641 [1988]). These traits may represent alternative expressions of a latent trait or endophenotype, which, in combination with other pathogenic elements, gives rise to schizophrenia.

During the development of the present invention, preliminary linkage analyses between the P50 ratio abnormality and 318 restriction fragment length polymorphism and tandem repeat DNA markers in the nine kindreds were conducted. DNA markers mapping to four chromosomal regions, one of which was 15q14, revealed small positive lod scores (maximum logarithm of the odds) assuming autosomal dominant transmission. Subsequently, the $\alpha 7$ nicotinic receptor gene was localized to the 15q14 region (Orr-Urtrege *et al.*, Genomics 26:399 [1995]; and Spitzer *et al.*, Arch. Gen. Psychiat., 35:773 [1978]). As converging evidence from neurobiological investigations implicated $\alpha 7$ receptor function in abnormal P50 inhibition, and the preliminary linkage study provided suggestive evidence for heritability of the trait near the chromosomal location of the $\alpha 7$ receptor gene, additional experiments, using informative markers at the $\alpha 7$ receptor gene locus were undertaken. Two new DNA polymorphic loci were isolated, namely D15S1360 from a yeast artificial chromosome (YAC) containing the $\alpha 7$ nicotinic receptor gene, and L76630 from an $\alpha 7$ -containing clone in a genomic phage library. These markers were used with over 500 highly polymorphic markers in a 10 centiMorgan resolution genome-wide scan of the nine

pedigrees. The results demonstrate a highly significant linkage between D15S1360 and the abnormality in P50 suppression.

Indeed, the data obtained during the development of the present invention strongly suggest that the P50 auditory sensory deficit in schizophrenia is genetically linked to the locus of the $\alpha 7$ nicotinic receptor gene on chromosome 15q14. Thus, the present invention provides the heretofore unknown linkage between nicotinic receptors and schizophrenia. The significant linkage obtained with the P50 ratio phenotype supports the value of this strategy. This provides methods for assessing the effects of therapy to correct abnormalities in $\alpha 7$ structure and/or function, as well as providing methods for developing and identifying drugs suitable for use in treating such abnormalities.

Although an understanding of the mechanism is not necessary in order to use the present invention, it has been suggested that the clinical illness may be less penetrant, because multiple genetic and non-genetic factors are required to produce clinical illness, whereas a specific biological defect may occur as the result of a single gene effect. Thus, some gene carriers would be expected to have abnormal P50 ratio, the more penetrant phenotype, but not schizophrenia, which is less penetrant. The lower lod scores observed during the development of the present invention with schizophrenia as a phenotype support that position; several kindreds had higher lod scores for P50 ratio than for schizophrenia because there were many family members with abnormal P50 ratios who did not have schizophrenia.

The possibility that the chromosome 15q13-14 region is involved in psychotic illness has also been investigated in relationship to other diseases. For example, psychoses resembling schizophrenia have been observed in Prader-Willi syndrome, a mental retardation linked to deletions and abnormal DNA imprinting in the 15q11-13 region (Clarke, Brit. J. Psychiat., 163:680 [1993]). The imprinting abnormality affects the expression of many genes in this region. Several families in Sephardic and other populations have co-existent schizophrenia and Marfan's syndrome (*i.e.*, a disease linked to dominant mutations in the fibrillin gene at 15q21; Sirota *et al.*, Br. J. Psychiat., 157: 433 [1990]; and Melissari *et al.*, *Pathologica* 87:78 [1995]). The co-

segregation of the two illnesses may be based on their chromosomal proximity. Psychosis also occurs in a large French Canadian kindred that has a recessive demyelination disease linked to markers at 15q14 (Casaubon *et al.*, Am. J. Hum. Genet., 58:28 [1996]). In addition, an Italian kindred contains two cousins with
5 psychotic illness and a partial trisomy of chromosome 15, derived independently from abnormal meioses involving a balanced familial translocation with a 15q13 breakpoint, that was present in each of their mothers. It was suggested that the new trisomies may have caused the *de novo* appearance of illness (Calzolari *et al.*, Am. J. Med. Genet., 67:154 [1996]). The present invention provides the means to determine to what extent
10 the appearance of psychoses in these families with other genetic abnormalities at 15q13-14 involves the $\alpha 7$ gene.

In addition to providing means to assess the risk for development of schizophrenia, the present invention also provides new data about the identity of neuronal abnormalities involved in its pathophysiology, as well as the means to
15 develop treatment methods and compounds, diagnostic methods and reagents, and models (*e.g.*, cell lines and transgenic animals) of these neuronal abnormalities. These results are consistent with clinical and neurobiological evidence for the involvement of the $\alpha 7$ nicotinic receptor gene in sensory gating deficits in schizophrenia.

The present invention also provides the means to determine the role the $\alpha 7$
20 receptor in the sensory processing defects and other abnormalities in schizophrenia. The finding of a significant linkage to support the role of the $\alpha 7$ nicotinic receptor in the pathophysiology of sensory and attentional disturbance in schizophrenia is unique. Many neurotransmitter systems have been hypothesized to be at least partly responsible for schizophrenia, but direct biological assessment of a specific neuronal receptor
25 function in human subjects is generally not feasible because of the brain's complexity and inaccessibility. The present invention provides compositions and methods to overcome these drawbacks. Genetic investigations, including linkage studies, have represented the critical test of the involvement of a particular mechanism in schizophrenia. The present invention provides methods and compositions to
30 complement and/or replace such tests for schizophrenia. Indeed, linkage at the $\alpha 7$

nicotinic receptor locus thus supports the neurobiological evidence that this gene plays a role in a pathophysiological aspect of schizophrenia, a role that prior to the present invention, had not been previously considered nor described, despite schizophrenics' well-known heavy dependence on nicotine.

II. Neuronal Nicotinic Receptor Subunit Family

As discussed above, during the development of the present invention, the $\alpha 7$ nicotinic receptor was associated with pathophysiological aspect(s) of schizophrenia. This receptor is a member of the neuronal nicotinic receptor subunit gene family, which is expressed in mammalian brain as pentameric, ligand-gated ion channels (Patrick *et al.*, Ann. NY Acad. Sci., 505:194 [1987]; Cooper *et al.*, Nature 350:235 [1991]; and Lindstrom *et al.*, Ann. NY Acad. Sci., 757:100 [1996]). In the muscle, five different types of subunits constitute the holoreceptor, but in brain only two types of subunits, designated as " α " and " β ," have been found (Galzi *et al.*, Ann. Rev. Pharmacol., 31:37 [1991]; and Lukas and Bencherif, Int. Rev. Neurobiol., 34:25 [1992]).

Neuronal receptors can be functionally differentiated into two principal classes which differ in their affinity for nicotine and the snake toxin, α -bungarotoxin (Marks and Collins, Mol. Pharmacol., 22:554 [1982]; Wonnacott, J. Neurochem., 47:1706 [1986]; Marks *et al.*, Mol. Pharmacol., 30:427 [1986]; and Amar *et al.*, FEBS 327:284 [1993]). Receptors that bind nicotine with high affinity contain $\alpha 2$ - $\alpha 6$ as ligand binding subunits and require an association with β subunits for functional expression (Goldman *et al.*, Cell 48:965 [1987]; Deneris *et al.*, Clin. Chem., 35:731 [1989]; and Wada *et al.*, J. Compar. Neurol., 284:314 [1989]). A second class of receptors ($\alpha 7$ - $\alpha 9$) bind nicotine with low affinity, have a high affinity for α -bungarotoxin, and function as homomeric ion channels in *in vitro* expression systems (Marks *et al.*, [1986], *supra*; Wonnacott, [1986], *supra*; Alkondon and Albuquerque, J. Pharm. Ex. Ther., 265:1455 [1993]; Amar *et al.*, FEBS 327:284 [1993]; and Zhang *et al.*, Neuron 12:167 [1994]). The $\alpha 7$ receptor is the only α -bungarotoxin-binding receptor

identified in mammalian brain, as $\alpha 8$ appears to be only expressed in chick (Schoepfer *et al.*, Neuron 5:35 [1990]) and $\alpha 9$ has limited expression in cochlear hair cells and pituitary (Elgoyhen *et al.*, Cell 79:705 [1994]). In addition, a cDNA clone of the human $\alpha 7$ was isolated from a human brain library (GenBank #U40583).

5 Expression and function of a specific subset of the nicotinic receptor family, the $\alpha 7$ receptor, has recently been implicated in a neuronal pathway controlling the filtering or gating of auditory stimuli in both human and rat brain (Adler *et al.*, Biol. Psych., 32:607 [1992]; Adler *et al.*, Am. J. Psychol., 150:1856 [1993]; Freedman *et al.*, Harvard Rev. Psychiat., 2:179 [1994]; and Leonard *et al.*, 1996). This sensory
10 processing mechanism is aberrant in a majority of subjects with schizophrenia (Freedman *et al.*, Schiz. Res., 4:233-243 [1991]). Pharmacological studies in both humans and rats suggest that the deficit in humans can be normalized by nicotine (Adler *et al.*, [1992] *supra*; and Adler *et al.*, [1993], *supra*) and reproduced in a rodent
15 model by antagonists of the low affinity $\alpha 7$ nicotinic receptor but not by high affinity antagonists (Luntz-Leybman *et al.*, Brain Res., 587:130 [1992]; and Rollins *et al.*, Soc. Neurosci. Abst., 22:1272 [1996]). Expression of α -bungarotoxin binding receptors is decreased in schizophrenic hippocampi by approximately 40% (Freedman *et al.*, Biol. Psychiat., 38:22 [1995]).

 During the development of the present invention, the locus D15S1360, a
20 polymorphic marker <120 kb from the full-length $\alpha 7$ nicotinic receptor gene at 15q14, was genetically linked to this auditory gating deficit in schizophrenic pedigrees. However, it is contemplated that other genes mapping to the 15q14 region are potential alternative or additional genetic candidates to $\alpha 7$ for pathogenic features of schizophrenia.

25 Also during the development of the present invention, the expression of the $\alpha 7$ nicotinic receptor in human postmortem brain was localized. This expression was found to be widely expressed at low levels in most nuclei, but regions of highest expression included those involved in processing of sensory information, such as the hippocampus, lateral and medial geniculates, and the reticular nucleus of the thalamus.

The present invention further provides the physical mapping of a full-length human genomic clone for the $\alpha 7$ receptor subunit and sequencing of a putative promoter region. The gene and promoter structure are similar to that of the chick $\alpha 7$. Additionally, a partial $\alpha 7$ gene duplication including exons 5-10 and intervening intronic sequence, which lies <1 Mb from the full-length gene has been identified. In addition, four novel exons at the 5' end of the duplicated $\alpha 7$ sequences were sequenced and intron/exon junctions identified. The duplicated $\alpha 7$ sequences were found to be expressed as alternatively spliced transcripts containing some or all of these novel exons.

The present invention also provides the structural organization of the human $\alpha 7$ neuronal nicotinic acetylcholine receptor gene and presents data indicating a partial gene duplication. Large insert genomic clones were isolated from YAC, BAC and PAC libraries. There are 10 exons in the gene; the splice junctions are consistent with consensus splice sites (Green, Ann. Rev. Cell. Biol., 7:559 [1991]; Lamond, Bioessays 15:595 [1993]) and have an identical location to those in the chick $\alpha 7$ gene (Matter-Sadzinski *et al.*, EMBO J., 11:4529 [1992]), the only species for which genomic $\alpha 7$ gene sequence has been previously published.

The promoter region of the gene was found to be 77% G/C, and contains no TATA box. It thus fits a growing group of eukaryotic promoters which demonstrate multiple transcription start sites (Maue *et al.*, Neuron 4:223 [1990]; and Sauerwald *et al.*, J. Biol. Chem., 265:14932 [1990]). The nucleotide sequence between the human and chick promoter regions was found to not be well conserved. However, there are consensus transcription factor binding sites located in similar positions in the two promoters (Matter-Sadzinski *et al.*, [1992] *supra*). These include SP-1 and AP-2 binding sites. SP-1 and AP-2 consensus motifs are frequently found in other ligand-gated ion channel genes (*See e.g.*, Bessis *et al.*, Nucl. Acids Res., 21:2185 [1993]), and may contribute to neuronal specificity.

A cyclic AMP response element (CREB) binding site motif was also identified in the human promotor, but is not found in the chick gene. The presence of this

CREB site in the human promoter is interesting since the mammalian $\alpha 7$ gene is known to be down-regulated by corticosterone (Pauly *et al.*, "Glucocorticoid Regulation of Sensitivity to Nicotine," in *The Biology of Nicotine: Current Research Issues*, Raven Press, New York, NY, [1992], pp. 121-139), which affects expression of the CREB-binding protein. Thus, it is contemplated that corticosterone and other glucocorticoids will affect the $\alpha 7$ gene in some embodiments of the present invention.

In addition, alternative splicing of the full-length $\alpha 7$ gene was detected during the development of the present invention. Six different splice variants were identified by sequencing of full length transcripts. However, only one, missing exon 3, did not interrupt the frame of translation.

Several important motifs which affect correct splicing of heterogeneous RNA were identified during the development of the present invention. For example, there are two Chi(X) sequences (consensus: CCTGGTGG) known to enhance splicing, present in the human $\alpha 7$ gene of the present invention; there is one in intron 4 and one in the 3'-UT of the cDNA. Another group of splice enhancers with sequence (T)GCATG(A), have been localized as well. There are seven motifs of this enhancer class in sequence identified for intron 2 (approximately >25 kb in size). An additional enhancer of this type has been found in the large intron 4. It is contemplated that additional splicing motifs may be localized in the human $\alpha 7$ sequence.

Exons 5-10 of the $\alpha 7$ nicotinic receptor gene were found to be duplicated in the human genome. The duplicated sequences lie within 1 Mb and are centromeric to the full-length $\alpha 7$ gene on chromosome 15. The evidence for the duplication includes mapping of the duplicated sequences to a different site on a YAC contig of the region. Additionally, heterozygous polymorphic sequences at exonic sites and at the L76630 locus, located 1.4 kb beyond the 3' end of the coding region, were detected in both a somatic cell chromosome 15 hybrid and in a single YAC (969b11) containing both the full-length gene and duplicated $\alpha 7$ exons. The apparent arrangement of the duplication is head to tail in relation to the full length gene.

Further complexity for the $\alpha 7$ gene structure was introduced when it was determined that some of the RACE clones isolated during cloning of a human $\alpha 7$

cDNA contained only exons 5-10, and additional non- $\alpha 7$ sequences 5' of exon 5. These sequences were identical to sequences found in several EST clones that were located by homology screening with $\alpha 7$ cDNA sequence. The EST clones also contained only exons 5-10 of the $\alpha 7$ gene, with the previously unreported sequences again 5' of exon 5. PCR products from genomic DNA and from YACs 948a10 and 953g6 revealed that these non- $\alpha 7$ sequences were present in genomic clones containing either the full-length gene or the duplicated $\alpha 7$ sequences, and four novel exons were defined. It is contemplated that these sequences are arranged as alternatively spliced exons, as the positions of the consensus splice junctions between them correspond to the spliced products seen in the RACE and EST clones. These new exons were designated as "3'- $\alpha 7A$," " $\alpha 7B$," " $\alpha 7C$ " and " $\alpha 7D-5'$." The RACE products were variable in their inclusion of exon B, similar to the EST clones.

Partial gene duplication has been implicated in human disease (*See e.g.*, Hu and Worton, *Hum. Mutat.*, 1:3 [1992]; Lehrman *et al.*, *Cell* 48:827 [1987]; and Dundunnen, *et al.*, *Am. J. Hum. Genet.*, 45:835 [1989]). Thus, it is contemplated that although transcription of mRNAs containing the novel exons was found to occur at levels similar to those of the full-length coding region, the novel exons may be expressed only from the duplicated $\alpha 7$ sequences. In addition, there is also evidence for novel exons in another gene on chromosome 15, the small nuclear riboprotein-N (SNRPN); these exons at both the 5'- and 3'-ends of the SNRPN gene are also transcribed as alternative mRNAs.

It is contemplated that the human alternative transcripts containing the novel exons $\alpha 7D$, $\alpha 7C$, $\alpha 7B$, and $\alpha 7A$, might be translated. These alternatives lack the $\alpha 7$ signal peptide and disulfide bridge, which have been shown to be necessary for assembly of the homologous alpha subunit in muscle (Blount and Merlie, *J. Cell Biol.*, 111:2613 [1990]). However, an alternatively spliced transcript of the muscle alpha, containing an additional exon, is expressed at equal levels to the correctly spliced isoform. It is also translated, but not assembled and is localized to the endoplasmic reticulum (Beeson *et al.*, *EMBO J.*, 9:2101 [1990]; and Newland *et al.*, *J. Physiol.*, 489:767 [1995]). It is contemplated that a similar localization occurs for the human

$\alpha 7$ alternative transcripts, containing the novel exons, if translated. However, it is not intended that the present invention be limited to any particular localization of these alternative transcripts.

Antibodies to the cytoplasmic loop of the chick $\alpha 7$, between membrane spanning regions III and IV, have been shown to detect $\alpha 7$ protein in pyramidal cells of rat hippocampus (Dominguez del Toro *et al.*, J. Comp. Neurol., 349:325 [1994]). However, during the development of the present invention, no α -bungarotoxin binding (*i.e.*, indicative of a functional receptor), was observed on the plasma membranes of these cells. Since protein, translated from alternative $\alpha 7$ mRNAs containing D-C-B-A-5-10, would have the epitope used as antigen for cytoplasmic loop antibodies, it is possible that sequestered, but dysfunctional $\alpha 7$ protein internally localized would be detected as well as cell surface protein. The abundance of the D-C-B-A-5-10 alternative transcripts, thus, raises the possibility that they are regulatory for functional expression of $\alpha 7$ nicotinic receptors.

Although the mechanism responsible for the gene duplication is unclear, and an understanding of the mechanism is not necessary in order to use the present invention, two *alu* repeats were found in the genomic clones. One is located in intron 4,500 bp upstream of exon 5. The second is located in the 3'-end of the gene outside of the poly-adenylation site. *Alu* repeats are known to have several possible functions, including as either positive or negative enhancers of transcription. In addition, they have also been shown to mediate duplication or deletion of DNA sequences (Schmid, Prog. Nucl. Acid Res., 53:283 [1996]; and Lehrman *et al.*, Cell 48:827 [1987]).

It is clear that the duplicated and expressed sequences involving the human $\alpha 7$ nicotinic receptor gene of the present invention provide the methods and compositions needed for mutation screening in disease. The present invention also provides methods and compositions for treatment (including, but not limited to gene therapy) of deficits in $\alpha 7$ expression and/or function.

The present invention provides methods and compositions needed to determine the control of $\alpha 7$ expression, through the use of the DNA sequences in its promoter

region, as well as DNA sequences located at its intron/exon boundaries, and DNA sequences present elsewhere in its introns. In addition, the present invention provides the locations and sequences of newly identified duplicated and additional exons. It is contemplated that these sequences may be involved in pathogenic mutational events.

5 Although the coding sequence of $\alpha 7$ shares some similarities between various animals (*e.g.*, chickens, rodents, and humans), the genomic structure provided in the present invention in the promoter and introns is unique to humans, and could not have been predicted based on the knowledge of the genome structure of any other species.

10 Furthermore, the coding region alone cannot be used for genetic screening of individuals to identify mutations, because the appropriate primers (*e.g.*, for PCR) are needed from introns positioned outside of the coding region. In addition, the genomic sequence is necessary for the production of cell lines and transgenic animals (*i.e.*, for models useful for the development of therapeutic targets in drug discovery). The present invention provides the needed genomic sequences and primers for genetic
15 screening methods and drug discovery.

III. Treatment and Diagnosis of Schizophrenia and Other Psychoses

The present invention provides methods and compositions for the development and identification of alternative means to diagnose and treat schizophrenia. The methods and compositions of the present invention will find use in the functional
20 assessment of $\alpha 7$ nicotinic receptors in schizophrenic patients, as well as for screening populations for deficits in receptor function. The present invention finds use in genetic screening methods for genetic and parentage counseling, as well as for identification of individuals at risk for developing schizophrenia.

25 The present invention also provides methods and compositions for modifying $\alpha 7$ nicotinic receptor function. For example, the present invention contemplates the development of genetic therapy methods to correct deficiencies in the receptor structure and/or function, as well as other therapeutic methods to enhance or decrease the function of the receptor, as appropriate for the treatment of any given individual.

It is also contemplated that the present invention will find use in relation to other psychosis. For example, the present invention will find use in the diagnosis and treatment of genetic disorders, in particular those genetic disorders known to have a genetic component associated with chromosome 15, such as Prader-Willi syndrome, Angelman's syndrome, etc., as well as other diseases, such as epilepsy (*e.g.*, juvenile myoclonic epilepsy), breast, and other types of cancers. The present invention also finds use in the diagnosis and treatment of nicotine-dependent illnesses, including, but not limited, to small cell lung carcinoma.

Indeed, it is contemplated that the present invention will find use in the development of antipsychotic drugs targeted to the $\alpha 7$ nicotinic receptor and/or the $\alpha 7$ nicotinic receptor subunit gene. For example, dimethylbenzylidene anabaseine (DMXB-A; [(2-4) Dimethoxy-benzylidene anabaseine hydrochloride]) and its congeners are selectively agonistic at the $\alpha 7$ receptor. During the development of the present invention, an animal model of the deficit observed in schizophrenics was used to show that DMXB-A is effective in repeated doses, whereas the effect of nicotine itself is completely inactivated after one dose. DMXB-A also has significantly less cardiovascular effects than nicotine, consistent with its antagonist effects at $\alpha 4$ - $\beta 2$ nicotinic receptors. Thus, it is contemplated that DMXB-A will find use as an anti-psychotic drug.

In addition to the physiological deficit found in schizophrenics and some of their relatives, similar deficits are also found as state-related changes in other psychotic disorders, including Parkinson's, Alzheimer's, mania and cocaine dependence. In stimulant dependence, neuroleptic anti-psychotic drugs have poor patient compliance, possibly due to their anhedonic, catecholamine-blocking effects. Thus, it is contemplated that nicotinic cholinergic therapeutic strategies, such as those developed using the methods and/or compositions of the present invention will be effective against a broad spectrum of clinical indications.

It is further contemplated that the present invention will be used to develop antibodies and other diagnostic reagents. For example, the present invention finds use

in the production of peptide antibodies using sequences identified using the present invention.

IV. Transgenic Animals

5 The present invention provides methods and compositions for production of transgenic animal models of schizophrenia, nicotine-dependent illnesses, and cancer. It is also contemplated that such systems as *Xenopus* oocytes will be used to express human $\alpha 7$ receptors and gene sequences of the present invention.

10 In preferred embodiments, transgenic mice are generated using microinjection of DNA containing $\alpha 7$ gene sequences into mammalian oocytes. However, equivalent transgenic mice can also be produced by homologous recombination in embryonic stem (ES) cells. Techniques for the isolation, culture, microinjection and implantation of a variety of mammalian oocytes (*e.g.*, murine, porcine, ovine, bovine, etc.) are known to the art.

15 Two mouse models are provided in the present invention. The first model involves introduction of an intact human $\alpha 7$ gene into the mouse genome by microinjection of a fertilized egg with DNA from the clone containing the full-length nAChR gene described in Example 8. The integrity of the clone in the transgenic mice is examined by PCR amplification, using all of the identified STSs on the clone map. Large flanking DNA sequences are included in this transgene, in order to ensure proper expression of the human $\alpha 7$ gene in the mice. The expression of the human $\alpha 7$ gene in mice is examined by an RNase protection assay designed to specifically detect the human $\alpha 7$ mRNA. This expression pattern coincides with the expression pattern of $\alpha 7$ in human tissues, as analyzed by Northern hybridization. The transgenic mouse model provides animals for determinations of $\alpha 7$ function in nicotine-dependence, nicotine-dependent illnesses, cancers associated with chromosome 15, schizophrenia, and other psychoses. These animals also facilitate the development of drugs and other therapeutics that affect the function of human $\alpha 7$ *in vivo*.

25 The second model is exemplified using transgenic mice which contain targeted disruptions of the $\alpha 7$ gene. These animals, termed "knockout" animals, lack the ability

to express $\alpha 7$ (" $\alpha 7$ knockouts"). In this model, mice are generated with a deletion specifically in the $\alpha 7$ gene, in order to allow assessment of phenotypic changes. In order to produce the transgenic knockout mice of the present invention, cloned human $\alpha 7$ gene sequences are used to disrupt the $\alpha 7$ gene in such a manner that $\alpha 7$ cannot be produced. In this model, two types of deletions are designed. The first removes the $\alpha 7$ gene entirely from the germline cells. The second type of deletion is engineered so as to provide control over the specific tissue and developmental stage in which $\alpha 7$ expression is interrupted. In the second model, the viability of the mutated animals is maintained, permitting analysis of the animals' phenotypes (including expression in specific tissues).

DEFINITIONS

To facilitate understanding of the invention, a number of terms are defined below.

The term " $\alpha 7$ gene" (or *Alpha-7*, or "Alpha-7 gene") refers to the full-length $\alpha 7$ nucleotide sequence. However, it is also intended that the term encompass fragments of the $\alpha 7$ sequence, such as those that encoded by SEQ ID NOS:95-103, as well as other domains within the full-length $\alpha 7$ nucleotide sequence. Furthermore, the terms "Alpha-7 nucleotide sequence" or "Alpha-7 polynucleotide sequence" (or " $\alpha 7$ nucleotide sequence" or " $\alpha 7$ polynucleotide sequence") encompasses DNA, cDNA, and RNA (*e.g.*, mRNA) sequences. In preferred embodiments, the $\alpha 7$ is human $\alpha 7$.

A "variant" of human $\alpha 7$ as used herein, refers to an amino acid sequence that is altered by one or more amino acids. The variant may have "conservative" changes, wherein a substituted amino acid has similar structural or chemical properties, (*e.g.*, replacement of leucine with isoleucine). More rarely, a variant may have "nonconservative" changes (*e.g.*, replacement of a glycine with a tryptophan). Similar minor variations may also include amino acid deletions or insertions, or both.

Guidance in determining which amino acid residues may be substituted, inserted, or deleted without abolishing biological or immunological activity may be found using computer programs well known in the art, for example, DNASTAR software.

5 The term "biologically active," as used herein, refers to a protein or other biologically active molecules (*e.g.*, catalytic RNA) having structural, regulatory, or biochemical functions of a naturally occurring molecule. Likewise, "immunologically active" refers to the capability of the natural, recombinant, or synthetic $\alpha 7$, or any oligopeptide or polynucleotide thereof, to induce a specific immune response in appropriate animals or cells and to bind with specific antibodies.

10 The term "agonist," as used herein, refers to a molecule which, when bound to $\alpha 7$, causes a change in $\alpha 7$, which modulates the activity of $\alpha 7$. Agonists may include proteins, nucleic acids, carbohydrates, or any other molecules which bind or interact with $\alpha 7$.

15 The terms "antagonist" or "inhibitor," as used herein, refer to a molecule which, when bound to $\alpha 7$, blocks or modulates the biological or immunological activity of $\alpha 7$. Antagonists and inhibitors may include proteins, nucleic acids, carbohydrates, or any other molecules which bind or interact with $\alpha 7$.

20 The term "modulate," as used herein, refers to a change or an alteration in the biological activity of $\alpha 7$. Modulation may be an increase or a decrease in protein activity, a change in binding characteristics, or any other change in the biological, functional, or immunological properties of $\alpha 7$.

25 The term "derivative," as used herein, refers to the chemical modification of a nucleic acid encoding $\alpha 7$, or the encoded $\alpha 7$. Illustrative of such modifications would be replacement of hydrogen by an alkyl, acyl, or amino group. A nucleic acid derivative would encode a polypeptide which retains essential biological characteristics of the natural molecule.

30 The term "gene" refers to a nucleic acid (*e.g.*, DNA) sequence that comprises coding sequences necessary for the production of a polypeptide or precursor (*e.g.*, human $\alpha 7$). The polypeptide can be encoded by a full length coding sequence or by any portion of the coding sequence so long as the desired activity or functional

properties (*e.g.*, enzymatic activity, ligand binding, signal transduction, etc.) of the full-length or fragment are retained. The term also encompasses the coding region of a structural gene and the including sequences located adjacent to the coding region on both the 5' and 3' ends for a distance of about 1 kb on either end such that the gene corresponds to the length of the full-length mRNA. The sequences which are located 5' of the coding region and which are present on the mRNA are referred to as 5' non-translated sequences. The sequences which are located 3' or downstream of the coding region and which are present on the mRNA are referred to as 3' non-translated sequences. The term "gene" encompasses both cDNA and genomic forms of a gene.

A genomic form or clone of a gene contains the coding region interrupted with non-coding sequences termed "introns" or "intervening regions" or "intervening sequences." Introns are segments of a gene which are transcribed into nuclear RNA (hnRNA); introns may contain regulatory elements such as enhancers. Introns are removed or "spliced out" from the nuclear or primary transcript; introns therefore are absent in the messenger RNA (mRNA) transcript. The mRNA functions during translation to specify the sequence or order of amino acids in a nascent polypeptide.

Where "amino acid sequence" is recited herein to refer to an amino acid sequence of a naturally occurring protein molecule, "amino acid sequence" and like terms, such as "polypeptide" or "protein" are not meant to limit the amino acid sequence to the complete, native amino acid sequence associated with the recited protein molecule.

In addition to containing introns, genomic forms of a gene may also include sequences located on both the 5' and 3' end of the sequences which are present on the RNA transcript. These sequences are referred to as "flanking" sequences or regions (these flanking sequences are located 5' or 3' to the non-translated sequences present on the mRNA transcript). The 5' flanking region may contain regulatory sequences such as promoters and enhancers which control or influence the transcription of the gene. The 3' flanking region may contain sequences which direct the termination of transcription, post-transcriptional cleavage and polyadenylation. The present invention provides DNA sequence of the $\alpha 7$ promoter (SEQ ID NO:101; *See*, Figure 8). The

present invention also provides DNA sequence for the region located 5' to the human $\alpha 7$ gene (SEQ ID NO:94; *See*, Figure 4).

5 "Peptide nucleic acid," as used herein, refers to a molecule which comprises an oligomer to which an amino acid residue, such as lysine, and an amino group have been added. These small molecules, also designated anti-gene agents, stop transcript elongation by binding to their complementary strand of nucleic acid (Nielsen, P.E. *et al.*, *Anticancer Drug Des.* 8:53-63 [1993]).

10 The term "wild-type" refers to a gene or gene product which has the characteristics of that gene or gene product when isolated from a naturally occurring source. A wild-type gene is that which is most frequently observed in a population and is thus arbitrarily designed the "normal" or "wild-type" form of the gene. In contrast, the term "modified" or "mutant" refers to a gene or gene product which displays modifications in sequence and or functional properties (*i.e.*, altered characteristics) when compared to the wild-type gene or gene product. It is noted that
15 naturally-occurring mutants can be isolated; these are identified by the fact that they have altered characteristics when compared to the wild-type gene or gene product.

As used herein, the terms "nucleic acid molecule encoding," "DNA sequence encoding," and "DNA encoding" refer to the order or sequence of deoxyribonucleotides along a strand of deoxyribonucleic acid. The order of these
20 deoxyribonucleotides determines the order of amino acids along the polypeptide (protein) chain. The DNA sequence thus codes for the amino acid sequence.

DNA molecules are said to have "5' ends" and "3' ends" because mononucleotides are reacted to make oligonucleotides or polynucleotides in a manner such that the 5' phosphate of one mononucleotide pentose ring is attached to the 3' oxygen of its neighbor in one direction via a phosphodiester linkage. Therefore, an
25 end of an oligonucleotides or polynucleotide, referred to as the "5' end" if its 5' phosphate is not linked to the 3' oxygen of a mononucleotide pentose ring and as the "3' end" if its 3' oxygen is not linked to a 5' phosphate of a subsequent mononucleotide pentose ring. As used herein, a nucleic acid sequence, even if internal
30 to a larger oligonucleotide or polynucleotide, also may be said to have 5' and 3' ends.

In either a linear or circular DNA molecule, discrete elements are referred to as being "upstream" or 5' of the "downstream" or 3' elements. This terminology reflects the fact that transcription proceeds in a 5' to 3' fashion along the DNA strand. The promoter and enhancer elements which direct transcription of a linked gene are generally located 5' or upstream of the coding region. However, enhancer elements can exert their effect even when located 3' of the promoter element and the coding region. Transcription termination and polyadenylation signals are located 3' or downstream of the coding region.

As used herein, the terms "an oligonucleotide having a nucleotide sequence encoding a gene" and "polynucleotide having a nucleotide sequence encoding a gene," means a nucleic acid sequence comprising the coding region of a gene or in other words the nucleic acid sequence which encodes a gene product. The coding region may be present in either a cDNA, genomic DNA or RNA form. When present in a DNA form, the oligonucleotide or polynucleotide may be single-stranded (*i.e.*, the sense strand) or double-stranded. Suitable control elements such as enhancers/promoters, splice junctions, polyadenylation signals, *etc.* may be placed in close proximity to the coding region of the gene if needed to permit proper initiation of transcription and/or correct processing of the primary RNA transcript. Alternatively, the coding region utilized in the expression vectors of the present invention may contain endogenous enhancers/promoters, splice junctions, intervening sequences, polyadenylation signals, *etc.* or a combination of both endogenous and exogenous control elements.

As used herein, the term "regulatory element" refers to a genetic element which controls some aspect of the expression of nucleic acid sequences. For example, a promoter is a regulatory element which facilitates the initiation of transcription of an operably linked coding region. Other regulatory elements are splicing signals, polyadenylation signals, termination signals, *etc.* (defined *infra*).

Transcriptional control signals in eukaryotes comprise "promoter" and "enhancer" elements. Promoters and enhancers consist of short arrays of DNA sequences that interact specifically with cellular proteins involved in transcription (T.

Maniatis *et al.*, Science 236:1237 [1987]). Promoter and enhancer elements have been isolated from a variety of eukaryotic sources including genes in yeast, insect and mammalian cells and viruses (analogous control elements, *i.e.*, promoters, are also found in prokaryote). The selection of a particular promoter and enhancer depends on what cell type is to be used to express the protein of interest. Some eukaryotic promoters and enhancers have a broad host range while others are functional in a limited subset of cell types (for review see, S.D. Voss *et al.*, Trends Biochem. Sci., 11:287 [1986]; and T. Maniatis *et al.*, *supra*). For example, the SV40 early gene enhancer is very active in a wide variety of cell types from many mammalian species and has been widely used for the expression of proteins in mammalian cells (R. Dijkema *et al.*, EMBO J. 4:761 [1985]). Two other examples of promoter/enhancer elements active in a broad range of mammalian cell types are those from the human elongation factor 1 α gene (T. Uetsuki *et al.*, J. Biol. Chem., 264:5791 [1989]; D.W. Kim *et al.*, Gene 91:217 [1990]; and S. Mizushima and S. Nagata, Nuc. Acids. Res., 18:5322 [1990]) and the long terminal repeats of the Rous sarcoma virus (C.M. Gorman *et al.*, Proc. Natl. Acad. Sci. USA 79:6777 [1982]) and the human cytomegalovirus (M. Boshart *et al.*, Cell 41:521 [1985]).

As used herein, the term "promoter/enhancer" denotes a segment of DNA which contains sequences capable of providing both promoter and enhancer functions (*i.e.*, the functions provided by a promoter element and an enhancer element, see above for a discussion of these functions). For example, the long terminal repeats of retroviruses contain both promoter and enhancer functions. The enhancer/promoter may be "endogenous" or "exogenous" or "heterologous." An "endogenous" enhancer/promoter is one which is naturally linked with a given gene in the genome. An "exogenous" or "heterologous" enhancer/promoter is one which is placed in juxtaposition to a gene by means of genetic manipulation (*i.e.*, molecular biological techniques) such that transcription of that gene is directed by the linked enhancer/promoter.

The presence of "splicing signals" on an expression vector often results in higher levels of expression of the recombinant transcript. Splicing signals mediate the removal of introns from the primary RNA transcript and consist of a splice donor and acceptor site (J. Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual*, 2nd ed., Cold Spring Harbor Laboratory Press, New York [1989], pp. 16.7-16.8). A commonly used splice donor and acceptor site is the splice junction from the 16S RNA of SV40.

Efficient expression of recombinant DNA sequences in eukaryotic cells requires expression of signals directing the efficient termination and polyadenylation of the resulting transcript. Transcription termination signals are generally found downstream of the polyadenylation signal and are a few hundred nucleotides in length. The term "poly A site" or "poly A sequence" as used herein denotes a DNA sequence which directs both the termination and polyadenylation of the nascent RNA transcript. Efficient polyadenylation of the recombinant transcript is desirable as transcripts lacking a poly A tail are unstable and are rapidly degraded. The poly A signal utilized in an expression vector may be "heterologous" or "endogenous." An endogenous poly A signal is one that is found naturally at the 3' end of the coding region of a given gene in the genome. A heterologous poly A signal is one which is isolated from one gene and placed 3' of another gene. A commonly used heterologous poly A signal is the SV40 poly A signal. The SV40 poly A signal is contained on a 237 bp *Bam*HI/*Bcl*II restriction fragment and directs both termination and polyadenylation (J. Sambrook, *supra*, at 16.6-16.7).

Eukaryotic expression vectors may also contain "viral replicons" or "viral origins of replication." Viral replicons are viral DNA sequences which allow for the extrachromosomal replication of a vector in a host cell expressing the appropriate replication factors. Vectors which contain either the SV40 or polyoma virus origin of replication replicate to high copy number (up to 10^4 copies/cell) in cells that express the appropriate viral T antigen. Vectors which contain the replicons from bovine papillomavirus or Epstein-Barr virus replicate extrachromosomally at low copy number (~100 copies/cell).

As used herein, the terms "complementary" or "complementarity" are used in reference to polynucleotides (*i.e.*, a sequence of nucleotides) related by the base-pairing rules. For example, for the sequence "A-G-T," is complementary to the sequence "T-C-A." Complementarity may be "partial," in which only some of the nucleic acids' bases are matched according to the base pairing rules. Or, there may be "complete" or "total" complementarity between the nucleic acids. The degree of complementarity between nucleic acid strands has significant effects on the efficiency and strength of hybridization between nucleic acid strands. This is of particular importance in amplification reactions, as well as detection methods which depend upon binding between nucleic acids.

The term "homology" refers to a degree of complementarity. There may be partial homology or complete homology (*i.e.*, identity). A partially complementary sequence is one that at least partially inhibits a completely complementary sequence from hybridizing to a target nucleic acid is referred to using the functional term "substantially homologous." The inhibition of hybridization of the completely complementary sequence to the target sequence may be examined using a hybridization assay (Southern or Northern blot, solution hybridization and the like) under conditions of low stringency. A substantially homologous sequence or probe will compete for and inhibit the binding (*i.e.*, the hybridization) of a completely homologous to a target under conditions of low stringency. This is not to say that conditions of low stringency are such that non-specific binding is permitted; low stringency conditions require that the binding of two sequences to one another be a specific (*i.e.*, selective) interaction. The absence of non-specific binding may be tested by the use of a second target which lacks even a partial degree of complementarity (*e.g.*, less than about 30% identity); in the absence of non-specific binding the probe will not hybridize to the second non-complementary target.

The art knows well that numerous equivalent conditions may be employed to comprise low stringency conditions; factors such as the length and nature (DNA, RNA, base composition) of the probe and nature of the target (DNA, RNA, base

composition, present in solution or immobilized, etc.) and the concentration of the salts and other components (*e.g.*, the presence or absence of formamide, dextran sulfate, polyethylene glycol) are considered and the hybridization solution may be varied to generate conditions of low stringency hybridization different from, but equivalent to, the above listed conditions. In addition, the art knows conditions which promote hybridization under conditions of high stringency (*e.g.*, increasing the temperature of the hybridization and/or wash steps, the use of formamide in the hybridization solution, etc.).

When used in reference to a double-stranded nucleic acid sequence such as a cDNA or genomic clone, the term "substantially homologous" refers to any probe which can hybridize to either or both strands of the double-stranded nucleic acid sequence under conditions of low stringency as described above.

A gene may produce multiple RNA species which are generated by differential splicing of the primary RNA transcript. cDNAs that are splice variants of the same gene will contain regions of sequence identity or complete homology (representing the presence of the same exon or portion of the same exon on both cDNAs) and regions of complete non-identity (for example, representing the presence of exon "A" on cDNA 1 wherein cDNA 2 contains exon "B" instead). Because the two cDNAs contain regions of sequence identity they will both hybridize to a probe derived from the entire gene or portions of the gene containing sequences found on both cDNAs; the two splice variants are therefore substantially homologous to such a probe and to each other.

When used in reference to a single-stranded nucleic acid sequence, the term "substantially homologous" refers to any probe which can hybridize (*i.e.*, it is the complement of) the single-stranded nucleic acid sequence under conditions of low stringency as described above.

As used herein, the term "hybridization" is used in reference to the pairing of complementary nucleic acids. Hybridization and the strength of hybridization (*i.e.*, the strength of the association between the nucleic acids) is impacted by such factors as the degree of complementarity between the nucleic acids, stringency of the conditions involved, the T_m of the formed hybrid, and the G:C ratio within the nucleic acids.

As used herein, the term " T_m " is used in reference to the "melting temperature." The melting temperature is the temperature at which a population of double-stranded nucleic acid molecules becomes half dissociated into single strands. The equation for calculating the T_m of nucleic acids is well known in the art. As indicated by standard references, a simple estimate of the T_m value may be calculated by the equation: $T_m = 81.5 + 0.41(\% G + C)$, when a nucleic acid is in aqueous solution at 1 M NaCl (*See e.g.*, Anderson and Young, Quantitative Filter Hybridization, in *Nucleic Acid Hybridization* [1985]). Other references include more sophisticated computations which take structural as well as sequence characteristics into account for the calculation of T_m .

As used herein the term "stringency" is used in reference to the conditions of temperature, ionic strength, and the presence of other compounds such as organic solvents, under which nucleic acid hybridizations are conducted. With "high stringency" conditions, nucleic acid base pairing will occur only between nucleic acid fragments that have a high frequency of complementary base sequences. Thus, conditions of "weak" or "low" stringency are often required with nucleic acids that are derived from organisms that are genetically diverse, as the frequency of complementary sequences is usually less.

"Amplification" is a special case of nucleic acid replication involving template specificity. It is to be contrasted with non-specific template replication (*i.e.*, replication that is template-dependent but not dependent on a specific template). Template specificity is here distinguished from fidelity of replication (*i.e.*, synthesis of the proper polynucleotide sequence) and nucleotide (ribo- or deoxyribo-) specificity. Template specificity is frequently described in terms of "target" specificity. Target

sequences are "targets" in the sense that they are sought to be sorted out from other nucleic acid. Amplification techniques have been designed primarily for this sorting out.

Template specificity is achieved in most amplification techniques by the choice of enzyme. Amplification enzymes are enzymes that, under conditions they are used, will process only specific sequences of nucleic acid in a heterogeneous mixture of nucleic acid. For example, in the case of Q β replicase, MDV-1 RNA is the specific template for the replicase (Kacian *et al.*, Proc. Natl. Acad. Sci. USA 69:3038 [1972]). Other nucleic acid will not be replicated by this amplification enzyme. Similarly, in the case of T7 RNA polymerase, this amplification enzyme has a stringent specificity for its own promoters (Chamberlin *et al.*, Nature 228:227 [1970]). In the case of T4 DNA ligase, the enzyme will not ligate the two oligonucleotides or polynucleotides, where there is a mismatch between the oligonucleotide or polynucleotide substrate and the template at the ligation junction (Wu and Wallace, Genomics 4:560 [1989]). Finally, *Taq* and *Pfu* polymerases, by virtue of their ability to function at high temperature, are found to display high specificity for the sequences bounded and thus defined by the primers; the high temperature results in thermodynamic conditions that favor primer hybridization with the target sequences and not hybridization with non-target sequences (Erlich (ed.), *PCR Technology*, Stockton Press [1989]).

As used herein, the term "amplifiable nucleic acid" is used in reference to nucleic acids which may be amplified by any amplification method. It is contemplated that "amplifiable nucleic acid" will usually comprise "sample template."

As used herein, the term "sample template" refers to nucleic acid originating from a sample which is analyzed for the presence of "target" (defined below). In contrast, "background template" is used in reference to nucleic acid other than sample template which may or may not be present in a sample. Background template is most often inadvertent. It may be the result of carryover, or it may be due to the presence of nucleic acid contaminants sought to be purified away from the sample. For example, nucleic acids from organisms other than those to be detected may be present as background in a test sample.

As used herein, the term "primer" refers to an oligonucleotide, whether occurring naturally as in a purified restriction digest or produced synthetically, which is capable of acting as a point of initiation of synthesis when placed under conditions in which synthesis of a primer extension product which is complementary to a nucleic acid strand is induced, (*i.e.*, in the presence of nucleotides and an inducing agent such as DNA polymerase and at a suitable temperature and pH). The primer is preferably single stranded for maximum efficiency in amplification, but may alternatively be double stranded. If double stranded, the primer is first treated to separate its strands before being used to prepare extension products. Preferably, the primer is an oligodeoxyribonucleotide. The primer must be sufficiently long to prime the synthesis of extension products in the presence of the inducing agent. The exact lengths of the primers will depend on many factors, including temperature, source of primer and the use of the method. The present invention provides sequences for numerous primers (*i.e.*, SEQ ID NOS:1-8, and 12-83).

As used herein, the term "probe" refers to an oligonucleotide (*i.e.*, a sequence of nucleotides), whether occurring naturally as in a purified restriction digest or produced synthetically, recombinantly or by PCR amplification, which is capable of hybridizing to another oligonucleotide of interest. A probe may be single-stranded or double-stranded. Probes are useful in the detection, identification and isolation of particular gene sequences. It is contemplated that any probe used in the present invention will be labelled with any "reporter molecule," so that is detectable in any detection system, including, but not limited to enzyme (*e.g.*, ELISA, as well as enzyme-based histochemical assays), fluorescent, radioactive, and luminescent systems. It is not intended that the present invention be limited to any particular detection

system or label. The present invention provides sequences for suitable for use as probes (*e.g.*, SEQ ID NO:9-11, as well as the primer sequences described above).

5 As used herein, the term "target," when used in reference to the polymerase chain reaction, refers to the region of nucleic acid bounded by the primers used for polymerase chain reaction. Thus, the "target" is sought to be sorted out from other nucleic acid sequences. A "segment" is defined as a region of nucleic acid within the target sequence.

10 As used herein, the term "polymerase chain reaction" ("PCR") refers to the method of Mullis (*See e.g.*, U.S. Patent Nos. 4,683,195 4,683,202, and 4,965,188, hereby incorporated by reference), which describe a method for increasing the concentration of a segment of a target sequence in a mixture of genomic DNA without cloning or purification. This process for amplifying the target sequence consists of introducing a large excess of two oligonucleotide primers to the DNA mixture containing the desired target sequence, followed by a precise sequence of thermal
15 cycling in the presence of a DNA polymerase. The two primers are complementary to their respective strands of the double stranded target sequence. To effect amplification, the mixture is denatured and the primers then annealed to their complementary sequences within the target molecule. Following annealing, the primers are extended with a polymerase so as to form a new pair of complementary
20 strands. The steps of denaturation, primer annealing and polymerase extension can be repeated many times (*i.e.*, denaturation, annealing and extension constitute one "cycle"; there can be numerous "cycles") to obtain a high concentration of an amplified segment of the desired target sequence. The length of the amplified segment of the desired target sequence is determined by the relative positions of the primers with
25 respect to each other, and therefore, this length is a controllable parameter. By virtue of the repeating aspect of the process, the method is referred to as the "polymerase chain reaction" (hereinafter "PCR"). Because the desired amplified segments of the target sequence become the predominant sequences (in terms of concentration) in the mixture, they are said to be "PCR amplified".

With PCR, it is possible to amplify a single copy of a specific target sequence in genomic DNA to a level detectable by several different methodologies (e.g., hybridization with a labeled probe; incorporation of biotinylated primers followed by avidin-enzyme conjugate detection; incorporation of ³²P-labeled deoxynucleotide triphosphates, such as dCTP or dATP, into the amplified segment). In addition to genomic DNA, any oligonucleotide or polynucleotide sequence can be amplified with the appropriate set of primer molecules. In particular, the amplified segments created by the PCR process itself are, themselves, efficient templates for subsequent PCR amplifications.

As used herein, the terms "PCR product," "PCR fragment," and "amplification product" refer to the resultant mixture of compounds after two or more cycles of the PCR steps of denaturation, annealing and extension are complete. These terms encompass the case where there has been amplification of one or more segments of one or more target sequences.

As used herein, the term "amplification reagents" refers to those reagents (deoxyribonucleotide triphosphates, buffer, etc.), needed for amplification except for primers, nucleic acid template and the amplification enzyme. Typically, amplification reagents along with other reaction components are placed and contained in a reaction vessel (test tube, microwell, etc.).

As used herein, the term "RT-PCR" refers to the replication and amplification of RNA sequences. In this method, reverse transcription is coupled to PCR, most often using a one enzyme procedure in which a thermostable polymerase is employed, as described in U.S. Patent No. 5,322,770, herein incorporated by reference. In RT-PCR, the RNA template is converted to cDNA due to the reverse transcriptase activity of the polymerase, and then amplified using the polymerizing activity of the polymerase (*i.e.*, as in other PCR methods).

As used herein, the terms "restriction endonucleases" and "restriction enzymes" refer to bacterial enzymes, each of which cut double-stranded DNA at or near a specific nucleotide sequence.

As used herein, the term "recombinant DNA molecule" as used herein refers to a DNA molecule which is comprised of segments of DNA joined together by means of molecular biological techniques.

As used herein, the term "antisense" is used in reference to RNA sequences which are complementary to a specific RNA sequence (*e.g.*, mRNA). Included within this definition are antisense RNA ("asRNA") molecules involved in gene regulation by bacteria. Antisense RNA may be produced by any method, including synthesis by splicing the gene(s) of interest in a reverse orientation to a viral promoter which permits the synthesis of a coding strand. Once introduced into an embryo, this transcribed strand combines with natural mRNA produced by the embryo to form duplexes. These duplexes then block either the further transcription of the mRNA or its translation. In this manner, mutant phenotypes may be generated. The term "antisense strand" is used in reference to a nucleic acid strand that is complementary to the "sense" strand. The designation (-) (*i.e.*, "negative") is sometimes used in reference to the antisense strand, with the designation (+) sometimes used in reference to the sense (*i.e.*, "positive") strand.

As used herein, the term "polyA⁺ RNA" refers to RNA molecules having a stretch of adenine nucleotides at the 3' end. This polyadenine stretch is also referred to as a "poly-A tail." Eukaryotic mRNA molecules contain poly-A tails and are referred to as polyA⁺ RNA.

The terms "in operable combination," "in operable order," and "operably linked" as used herein refer to the linkage of nucleic acid sequences in such a manner that a nucleic acid molecule capable of directing the transcription of a given gene and/or the synthesis of a desired protein molecule is produced. The term also refers to the linkage of amino acid sequences in such a manner so that a functional protein is produced.

The term "isolated" when used in relation to a nucleic acid, as in "an isolated oligonucleotide" or "isolated polynucleotide" refers to a nucleic acid sequence that is identified and separated from at least one contaminant nucleic acid with which it is ordinarily associated in its natural source. Isolated nucleic acid is such present in a

form or setting that is different from that in which it is found in nature. In contrast, non-isolated nucleic acids as nucleic acids such as DNA and RNA found-in the state they exist in nature. For example, a given DNA sequence (*e.g.*, a gene) is found on the host cell chromosome in proximity to neighboring genes; RNA sequences, such as
5 a specific mRNA sequence encoding a specific protein, are found in the cell as a mixture with numerous other mRNA s which encode a multitude of proteins.

However, isolated nucleic acid encoding a mammalian $\alpha 7$ protein includes, by way of example, such nucleic acid in cells ordinarily expressing an $\alpha 7$ protein where the nucleic acid is in a chromosomal location different from that of natural cells, or is
10 otherwise flanked by a different nucleic acid sequence than that found in nature. The isolated nucleic acid, oligonucleotide, or polynucleotide may be present in single-stranded or double-stranded form. When an isolated nucleic acid, oligonucleotide or polynucleotide is to be utilized to express a protein, the oligonucleotide or polynucleotide will contain at a minimum the sense or coding strand (*i.e.*, the
15 oligonucleotide or polynucleotide may single-stranded), but may contain both the sense and anti-sense strands (*i.e.*, the oligonucleotide or polynucleotide may be double-stranded).

As used herein, a "portion of a chromosome" refers to a discrete section of the chromosome. Chromosomes are divided into sites or sections by cytogeneticists as
20 follows: the short (relative to the centromere) arm of a chromosome is termed the "p" arm; the long arm is termed the "q" arm. Each arm is then divided into 2 regions termed region 1 and region 2 (region 1 is closest to the centromere). Each region is further divided into bands. The bands may be further divided into sub-bands. For example, the 11p15.5 portion of human chromosome 11 is the portion located on
25 chromosome 11 (11) on the short arm (p) in the first region (1) in the 5th band (5) in sub-band 5 (.5). A portion of a chromosome may be "altered;" for instance the entire portion may be absent due to a deletion or may be rearranged (*e.g.*, inversions, translocations, expanded or contracted due to changes in repeat regions). In the case of a deletion, an attempt to hybridize (*i.e.*, specifically bind) a probe homologous to a

particular portion of a chromosome could result in a negative result (*i.e.*, the probe could not bind to the sample containing genetic material suspected of containing the missing portion of the chromosome). Thus, hybridization of a probe homologous to a particular portion of a chromosome may be used to detect alterations in a portion of a chromosome.

The term "sequences associated with a chromosome" means preparations of chromosomes (*e.g.*, spreads of metaphase chromosomes), nucleic acid extracted from a sample containing chromosomal DNA (*e.g.*, preparations of genomic DNA); the RNA which is produced by transcription of genes located on a chromosome (*e.g.*, hnRNA and mRNA) and cDNA copies of the RNA transcribed from the DNA located on a chromosome. Sequences associated with a chromosome may be detected by numerous techniques including probing of Southern and Northern blots and *in situ* hybridization to RNA, DNA or metaphase chromosomes with probes containing sequences homologous to the nucleic acids in the above listed preparations.

As used herein the term "coding region" when used in reference to structural gene refers to the nucleotide sequences which encode the amino acids found in the nascent polypeptide as a result of translation of a mRNA molecule. The coding region is bounded, in eukaryotes, on the 5' side by the nucleotide triplet "ATG" which encodes the initiator methionine and on the 3' side by one of the three triplets which specify stop codons (*i.e.*, TAA, TAG, TGA).

As used herein, the term "structural gene" refers to a DNA sequence coding for RNA or a protein. In contrast, "regulatory genes" are structural genes which encode products which control the expression of other genes (*e.g.*, transcription factors).

As used herein, the term "purified" or "to purify" refers to the removal of contaminants from a sample. For example, anti- $\alpha 7$ antibodies are purified by removal of contaminating non-immunoglobulin proteins; they are also purified by the removal of immunoglobulin that does not bind $\alpha 7$. The removal of non-immunoglobulin proteins and/or the removal of immunoglobulins that do not bind $\alpha 7$ results in an increase in the percent of $\alpha 7$ -reactive immunoglobulins in the sample. In another

example, recombinant $\alpha 7$ polypeptides are expressed in bacterial host cells and the polypeptides are purified by the removal of host cell proteins; the percent of recombinant $\alpha 7$ polypeptides is thereby increased in the sample.

5 The term "recombinant DNA molecule" as used herein refers to a DNA molecule which is comprised of segments of DNA joined together by means of molecular biological techniques.

The term "recombinant protein" or "recombinant polypeptide" as used herein refers to a protein molecule which is expressed from a recombinant DNA molecule.

10 The term "native protein" as used herein to indicate that a protein does not contain amino acid residues encoded by vector sequences; that is the native protein contains only those amino acids found in the protein as it occurs in nature. A native protein may be produced by recombinant means or may be isolated from a naturally occurring source.

15 As used herein the term "portion" when in reference to a protein (as in "a portion of a given protein") refers to fragments of that protein. The fragments may range in size from four amino acid residues to the entire amino acid sequence minus one amino acid.

20 As used herein, the term "fusion protein" refers to a chimeric protein containing the protein of interest (*i.e.*, mouse or human $\alpha 7$ and fragments thereof) joined to an exogenous protein fragment (the fusion partner which consists of a non- $\alpha 7$ protein). The fusion partner may enhance solubility of the $\alpha 7$ protein as expressed in a host cell, may provide an affinity tag to allow purification of the recombinant fusion protein from the host cell or culture supernatant, or both. If desired, the fusion protein may be removed from the protein of interest (*i.e.*, $\alpha 7$ protein or fragments thereof) by
25 a variety of enzymatic or chemical means known to the art.

The term "Southern blot," refers to the analysis of DNA on agarose or acrylamide gels to fractionate the DNA according to size followed by transfer of the DNA from the gel to a solid support, such as nitrocellulose or a nylon membrane. The immobilized DNA is then probed with a labeled probe to detect DNA species
30 complementary to the probe used. The DNA may be cleaved with restriction enzymes

prior to electrophoresis. Following electrophoresis, the DNA may be partially depurinated and denatured prior to or during transfer to the solid support. Southern blots are a standard tool of molecular biologists (J. Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Press, NY, pp 9.31-9.58 [1989]).

5 The term "Northern blot," as used herein refers to the analysis of RNA by electrophoresis of RNA on agarose gels to fractionate the RNA according to size followed by transfer of the RNA from the gel to a solid support, such as nitrocellulose or a nylon membrane. The immobilized RNA is then probed with a labeled probe to detect RNA species complementary to the probe used. Northern blots are a standard
10 tool of molecular biologists (J. Sambrook, J. *et al.*, *supra*, pp 7.39-7.52 [1989]).

 The term "Western blot" refers to the analysis of protein(s) (or polypeptides) immobilized onto a support such as nitrocellulose or a membrane. The proteins are run on acrylamide gels to separate the proteins, followed by transfer of the protein from the gel to a solid support, such as nitrocellulose or a nylon membrane. The
15 immobilized proteins are then exposed to antibodies with reactivity against an antigen of interest. The binding of the antibodies may be detected by various methods, including the use of radiolabelled antibodies.

 The term "antigenic determinant" as used herein refers to that portion of an antigen that makes contact with a particular antibody (*i.e.*, an epitope). When a
20 protein or fragment of a protein is used to immunize a host animal, numerous regions of the protein may induce the production of antibodies which bind specifically to a given region or three-dimensional structure on the protein; these regions or structures are referred to as antigenic determinants. An antigenic determinant may compete with the intact antigen (*i.e.*, the "immunogen" used to elicit the immune response) for
25 binding to an antibody.

 The terms "specific binding" or "specifically binding" when used in reference to the interaction of an antibody and a protein or peptide means that the interaction is dependent upon the presence of a particular structure (*i.e.*, the antigenic determinant or epitope) on the protein; in other words the antibody is recognizing and binding to a

specific protein structure rather than to proteins in general. For example, if an antibody is specific for epitope "A," the presence of a protein containing epitope A (or free, unlabelled A) in a reaction containing labelled "A" and the antibody will reduce the amount of labelled A bound to the antibody.

5 The present invention also contemplates "non-human animals" comprising any non-human animal capable of overexpressing $\alpha 7$ mRNA and/or proteins. Such non-human animals include vertebrates such as rodents, non-human primates, ovines, bovines, ruminants, lagomorphs, porcines, caprines, equines, canines, felines, aves, etc. Preferred non-human animals are selected from the order Rodentia, most preferably
10 mice. The term "order Rodentia" refers to rodents (*i.e.*, placental mammals [Class Euthria] which include the family Muridae (rats and mice).

 The "non-human animals having a genetically engineered genotype" of the invention are preferably produced by experimental manipulation of the genome of the germline of the non-human animal. These genetically engineered non-human animals
15 may be produced by several methods including the introduction of a "transgene" comprising nucleic acid (usually DNA) into an embryonal target cell or integration into a chromosome of the somatic and/or germ line cells of a non-human animal by way of human intervention, such as by the methods described herein. Non-human animals which contain a transgene are referred to as "transgenic non-human animals."
20 A transgenic animal is an animal whose genome has been altered by the introduction of a transgene.

 The term "transgene" as used herein refers to a foreign gene that is placed into an organism by introducing the foreign gene into newly fertilized eggs or early embryos. The term "foreign gene" refers to any nucleic acid (*e.g.*, gene sequence)
25 which is introduced into the genome of an animal by experimental manipulations and may include gene sequences found in that animal so long as the introduced gene does not reside in the same location as does the naturally-occurring gene.

 As used herein, the term "vector" is used in reference to nucleic acid molecules that transfer DNA segment(s) from one cell to another. The term "vehicle" is
30 sometimes used interchangeably with "vector."

The term "expression vector" as used herein refers to a recombinant DNA molecule containing a desired coding sequence and appropriate nucleic acid sequences necessary for the expression of the operably linked coding sequence in a particular host organism. Nucleic acid sequences necessary for expression in prokaryotes usually include a promoter, an operator (optional), and a ribosome binding site, often along with other sequences. Eukaryotic cells are known to utilize promoters, enhancers, and termination and polyadenylation signals.

The terms "overexpression" and "overexpressing" and grammatical equivalents, are used in reference to levels of mRNA to indicate a level of expression approximately 3-fold higher than that typically observed in a given tissue in a control or non-transgenic animal. Levels of mRNA are measured using any of a number of techniques known to those skilled in the art including, but not limited to Northern blot analysis. Appropriate controls are included on the Northern blot to control for differences in the amount of RNA loaded from each tissue analyzed (*e.g.*, the amount of 28S rRNA, an abundant RNA transcript present at essentially the same amount in all tissues, present in each sample can be used as a means of normalizing or standardizing the $\alpha 7$ mRNA-specific signal observed on Northern blots). The amount of mRNA present in the band corresponding in size to the correctly spliced $\alpha 7$ transgene RNA is quantified; other minor species of RNA which hybridize to the transgene probe are not considered in the quantification of the expression of the transgenic mRNA.

The term "transfection" as used herein refers to the introduction of foreign DNA into eukaryotic cells. Transfection may be accomplished by a variety of means known to the art including calcium phosphate-DNA co-precipitation, DEAE-dextran-mediated transfection, polybrene-mediated transfection, electroporation, microinjection, liposome fusion, lipofection, protoplast fusion, retroviral infection, and biolistics.

The term "stable transfection" or "stably transfected" refers to the introduction and integration of foreign DNA into the genome of the transfected cell. The term "stable transfectant" refers to a cell which has stably integrated foreign DNA into the genomic DNA.

The term "transient transfection" or "transiently transfected" refers to the introduction of foreign DNA into a cell where the foreign DNA fails to integrate into the genome of the transfected cell. The foreign DNA persists in the nucleus of the transfected cell for several days. During this time the foreign DNA is subject to the regulatory controls that govern the expression of endogenous genes in the chromosomes. The term "transient transfectant" refers to cells which have taken up foreign DNA but have failed to integrate this DNA.

The term "calcium phosphate co-precipitation" refers to a technique for the introduction of nucleic acids into a cell. The uptake of nucleic acids by cells is enhanced when the nucleic acid is presented as a calcium phosphate-nucleic acid co-precipitate. The original technique of Graham and van der Eb (Graham and van der Eb, *Virology*, 52:456 [1973]), has been modified by several groups to optimize conditions for particular types of cells. The art is well aware of these numerous modifications.

As used herein, the term "selectable marker" refers to the use of a gene which encodes an enzymatic activity that confers the ability to grow in medium lacking what would otherwise be an essential nutrient (*e.g.*, the *HIS3* gene in yeast cells); in addition, a selectable marker may confer resistance to an antibiotic or drug upon the cell in which the selectable marker is expressed. Selectable markers may be "dominant"; a dominant selectable marker encodes an enzymatic activity which can be detected in any eukaryotic cell line. Examples of dominant selectable markers include the bacterial aminoglycoside 3' phosphotransferase gene (also referred to as the *neo* gene) which confers resistance to the drug G418 in mammalian cells, the bacterial hygromycin G phosphotransferase (*hyg*) gene which confers resistance to the antibiotic hygromycin and the bacterial xanthine-guanine phosphoribosyl transferase gene (also referred to as the *gpt* gene) which confers the ability to grow in the presence of mycophenolic acid. Other selectable markers are not dominant in that their use must be in conjunction with a cell line that lacks the relevant enzyme activity. Examples of non-dominant selectable markers include the thymidine kinase (*tk*) gene which is used

in conjunction with *tk* cell lines, the CAD gene which is used in conjunction with CAD-deficient cells and the mammalian hypoxanthine-guanine phosphoribosyl transferase (*hprt*) gene which is used in conjunction with *hprt* cell lines. A review of the use of selectable markers in mammalian cell lines is provided in Sambrook, J. *et al.*, *Molecular Cloning: A Laboratory Manual*, 2nd ed., Cold Spring Harbor Laboratory Press, New York (1989) pp.16.9-16.15.

As used herein, the term "cell culture" refers to any *in vitro* culture of cells. Included within this term are continuous cell lines (*e.g.*, with an immortal phenotype), primary cell cultures, finite cell lines (*e.g.*, non-transformed cells), and any other cell population maintained *in vitro*.

The term "compound" refers to any chemical entity, pharmaceutical, drug, and the like that can be used to treat or prevent a disease, illness, sickness, or disorder of bodily function. Compounds comprise both known and potential therapeutic compounds. A compound can be determined to be therapeutic by screening using the screening methods of the present invention. A "known therapeutic compound" refers to a therapeutic compound that has been shown (*e.g.*, through animal trials or prior experience with administration to humans) to be effective in such treatment. In other words, a known therapeutic compound is not limited to a compound efficacious in the treatment of cancer.

The term "test compound" refers to any chemical entity, pharmaceutical, drug, and the like that can be used to treat or prevent a disease, illness, sickness, or disorder of bodily function. Test compounds comprise both known and potential therapeutic compounds. A test compound can be determined to be therapeutic by screening using the methods of the present invention. A "known therapeutic compound" refers to a therapeutic compound that has been shown (*e.g.*, through animal trials or prior experience with administration to humans) to be effective in such treatment or prevention. In other words, a known therapeutic compound is not limited to a compound efficacious in the treatment of $\alpha 7$ instability or inactivity in animals.

A "composition comprising a given polynucleotide sequence" as used herein refers broadly to any composition containing the given polynucleotide sequence. The composition may comprise an aqueous solution. Compositions comprising polynucleotide sequences encoding human $\alpha 7$ (e.g., SEQ ID NO:____) or fragments thereof (e.g., SEQ ID NO:____, and fragments thereof) may be employed as hybridization probes. In this case, the human $\alpha 7$ -encoding polynucleotide sequences are typically employed in an aqueous solution containing salts (e.g., NaCl), detergents (e.g., SDS) and other components (e.g., Denhardt's solution, dry milk, salmon sperm DNA, etc.).

The term "sample" as used herein is used in its broadest sense. A sample suspected of containing a human chromosome or sequences associated with a human chromosome may comprise a cell, chromosomes isolated from a cell (e.g., a spread of metaphase chromosomes), genomic DNA (in solution or bound to a solid support such as for Southern blot analysis), RNA (in solution or bound to a solid support such as for Northern blot analysis), cDNA (in solution or bound to a solid support) and the like. A sample suspected of containing a protein may comprise a cell, a portion of a tissue, an extract containing one or more proteins and the like.

The term "test $\alpha 7$ " refers to a sample suspected of containing $\alpha 7$. The concentration of $\alpha 7$ in the test sample is determined by various means, and may be compared with a "quantitated amount of $\alpha 7$ " (i.e., a positive control sample containing a known amount of $\alpha 7$), in order to determine whether the concentration of test $\alpha 7$ in the sample is within the range usually found within samples from wild-type organisms. Thus, comparison of the positive control with the test sample allows the determination to be made whether a particular individual produces a "normal" amount of $\alpha 7$, is deficient in production of $\alpha 7$, or produces a concentration of $\alpha 7$ that is greater than normal. It is intended that such test methods also contain "negative" controls (i.e., samples that are known to contain no $\alpha 7$). Furthermore, it is intended that the testing be conducted using the $\alpha 7$ gene, $\alpha 7$ mRNA, and/or $\alpha 7$ protein (or polypeptides), or fragments of any of these.

EXPERIMENTAL

The following examples are provided in order to demonstrate and further illustrate certain preferred embodiments and aspects of the present invention and are not to be construed as limiting the scope thereof.

5 In the experimental disclosure which follows, the following abbreviations apply: nAChR (nicotinic acetylcholine receptor); °C (degrees Centigrade); rpm (revolutions per minute); BSA (bovine serum albumin); H₂O (water); HCl (hydrochloric acid); aa (amino acid); bp (base pair); kb or kbp (kilobase pair); Mb (megabase pair); kD (kilodaltons); gm or g (grams); µg (micrograms); mg
10 (milligrams); ng (nanograms); µl (microliters); ml (milliliters); mm (millimeters); nm (nanometers); µm (micrometer); M (molar); mM (millimolar); µM (micromolar); nM (nanomolar); pM (picomolar); U or u (units); V (volts); MW (molecular weight); sec (seconds); min(s) (minute/minutes); hr(s) (hour/hours); dNTP (deoxynucleotide); MgCl₂ (magnesium chloride); NaCl (sodium chloride); KCl (potassium chloride); DTT
15 (dithiotreitol); DMSO (dimethyl sulfoxide); NaOH (sodium hydroxide); 3'UT (3'-untranslated region); OD₂₈₀ (optical density at 280 nm); OD₆₀₀ (optical density at 600 nm); EST (expressed sequence tag); PAGE (polyacrylamide gel electrophoresis); PBS (phosphate buffered saline [150 mM NaCl, 10 mM sodium phosphate buffer, pH 7.2]); PCR (polymerase chain reaction); DMEM (Dulbecco's Modified Eagle Medium); PEG
20 (polyethylene glycol); PMSF (phenylmethylsulfonyl fluoride); RT-PCR (reverse transcription PCR); SDS (sodium dodecyl sulfate); SSC (saline-sodium citrate buffer); Tris (tris(hydroxymethyl)aminomethane); w/v (weight to volume); v/v (volume to volume); YAC (yeast artificial chromosome); BAC (bacterial artificial chromosome); PAC (P1 artificial chromosome); RACE (Rapid Amplification of cDNA Ends); TAFE
25 (Transverse Alternating Field Electrophoresis); lod (maximum logarithm of the odds); STS (sequence-tagged site); Beckman (Beckman Instruments, Inc., Fullerton, CA); Amersham (Amersham Life Science, Inc. Arlington Heights, IL); Qiagen (Qiagen Inc., Santa Clarita, CA); Genome Systems (Genome Systems, St. Louis, MO, USA); ICN (ICN Pharmaceuticals, Inc., Costa Mesa, CA); Amicon (Amicon, Inc., Beverly, MA);
30 NCBI (National Center for Biotechnology Information, Bethesda, MD); ATCC

(American Type Culture Collection, Rockville, MD); Research Genetics (Research Genetics, Huntsville, AL); Pharmacia (Pharmacia and Upjohn Diagnostics, Kalamazoo, MI); Boehringer-Mannheim (Boehringer-Mannheim, Indianapolis, IN); National Biosciences (National Biosciences, Inc., Plymouth MN); MJ Research (MJ Research, Watertown, MA); Perkin-Elmer (Perkin-Elmer, Foster City, CA); BioRad (BioRad, Richmond, CA); Clontech (CLONTECH Laboratories, Palo Alto, CA); Gibco, GIBCO BRL, or Gibco BRL (Life Technologies, Inc., Gaithersburg, MD); Gene Codes (Gene Codes Corporation, Ann Arbor, MI); Invitrogen (Invitrogen Corp., San Deigo, CA); Kodak (Eastman Kodak Co., New Haven, CT); Promega (Promega, Corp., Madison, WI); New England Biolabs (New England Biolabs, Inc., Beverly, MA); Novagen (Novagen, Inc., Madison, WI); Pharmacia (Pharmacia, Inc., Piscataway, NJ); Schleicher & Schuell (Schleicher and Schuell, Inc., Keene, NH); Sigma (Sigma Chemical Co., St. Louis, MO); Sorvall (Sorvall Instruments, a subsidiary of DuPont Co., Biotechnology Systems, Wilmington, DE); Stratagene (Stratagene Cloning Systems, La Jolla, CA); Whatman (Whatman LabSales, Hillsboro, OR); Bethyl Laboratories (Bethyl Laboratories, Montgomery, TX); Ambion (Ambion, Inc., Austin, TX); and Zeiss (Carl Zeiss, Inc., Thornwood, NY).

Unless otherwise indicated, all restriction enzymes were obtained from New England BioLabs and were used according to the manufacturer's instructions.

EXAMPLE 1

Samples

Samples were obtained from various normal individuals for use as controls in the Examples described below. To prepare these samples, blood was drawn from normal subjects, seen in the Denver Schizophrenia Center. Of the 43 subjects used for the polymorphism analysis, 22 were female and 21 were male. There were 38 Caucasians, 2 Blacks, 1 Asian and 2 Hispanics. None of the subjects had a history of mental illness nor a family history of mental illness.

In addition to the "normal" samples, pedigrees were selected for presence of at least two cases of schizophrenia in a nuclear family. Two psychiatrists made clinical diagnoses of schizophrenia, chronic type, blind to pedigree and genetic information, using Research Diagnostic Criteria (Spitzer *et al.*, Arch. Gen. Psychiat., 35:773 [1978]; and Endicott and Spitzer, Arch. Gen. Psychiat., 35:837 [1978]). Nine families with 104 members were studied (*i.e.*, nine pedigrees containing individuals diagnosed with schizophrenia were analyzed). All subjects gave written informed consent. Blood was also drawn from these individuals for DNA analysis.

DNA was extracted from blood samples as described by Miller *et al.*, (Miller *et al.*, Nuc. Acids. Res., 16:1215 [1988]) with one additional step. Briefly, red blood cells were lysed by incubating 10-15 ml of anticoagulated blood at 4°C for 10 minutes in 40 ml blood cell lysis solution (BCL) (BCL contains 0.3 M sucrose, 0.01 M Tris HCl pH 7.5, 0.005 M MgCl₂ and 1% Triton X-100) with occasional rocking to mix. The cells were then centrifuged at 850xg at 4°C for 15 minutes. The pellet was resuspended by repeated pipetting with a 1 ml wide bore glass pipet in 30 ml BCL (4°C) and centrifuged as before.

DNA was then extracted from the pellet as described by Miller *et al.*, (Miller *et al.*, Nucl. Acids. Res., 16:1215 [1988]). Briefly, the pellet was resuspended as before in 3 ml Nuclei Lysis buffer (NL) (NL contains 0.075 M NaCl, and 0.024 M EDTA pH 8.0). Then, 200 µl of 10% SDS, 440 µl of digest diluent (1% SDS, 2 mM Na₂EDTA), and 60 µl of Proteinase K (20 mg/ml stock) were then added to the suspension. The suspension was then incubated at 37°C for 16-20 hours with gentle mixing by inversion. Following this digestion, 1 ml of saturated (approx. 6 M) NaCl was added and then the suspension briefly (15 seconds) was vigorously shaken. The suspension was then centrifuged at 1340xg at room temperature for 15 minutes. The supernatant was transferred to a new tube, leaving the pellet at the bottom of the previous tube undisturbed. Exactly 2 volumes of absolute ethanol were added. The tube was then inverted several times until the DNA pellet was visible and floated to the top. The pellet was then transferred to a new tube. The pellet was resuspended in 0.67 ml TE

pH 8 (10 mM Tris, 1 mM EDTA) by gently mixing on a roller drum for 3-5 days at 37°C.

In addition to the samples described above, a chromosome 15 somatic cell hybrid line, R379-2B2 generously provided by Dr. Carol Jones (The Eleanor Roosevelt
5 Institute for Cancer Research, Denver, CO), was also used. This cell line was cultured in Ham's F12, supplemented with 5% fetal bovine serum and 10 µg/ml gentamicin.

Another cell line, the human neuroblastoma cell line, SH-SY5Y (Biedler *et al.*, Cancer Res., 38:3751 [1978]), was obtained from Dr. June Biedler (Memorial Sloan-Kettering Cancer Center, New York, NY), and grown in DMEM/Ham's F12 (1:1 ratio,
10 supplemented with 15% fetal bovine serum, 4 mM glutamine, and 10 µg/ml gentamicin.

EXAMPLE 2

Genomic Clone Isolation

In this Example, YAC clones were identified by PCR screening of two
15 genomic libraries, namely the St. Louis YAC library (Burke *et al.*, Science 236:806 [1987]) and the CEPH YAC Library 3 (Albertsen *et al.*, Proc. Natl. Acad. Sci., 87:4256 [1990]), using $\alpha 7$ cDNA specific primers and methods known in the art (See *e.g.*, Brownstein *et al.*, Science 244:1348 [1989]; Chumakov *et al.*, Nature 359:380 [1992]; and Dracopoli *et al.*, *Current Protocols in Human Genetics*, John Wiley &
20 Sons, Inc., New York, NY [1994])

Additional YACs, positive for loci in the $\alpha 7$ nAChR region were identified initially by using Infoclone on the CEPH/Genethon Integrated Map (www.cephb.fr/ceph-genethon-map.html). Loci on the YAC contig were verified by
25 PCR screening with either $\alpha 7$ primer sets or primer sets for the specific polymorphic markers listed in the YAC contig (See, Figure 6), which are available from either the CEPH database or GenBank. The PCR conditions were 94°C for 2 minutes, 1 cycle;

followed by 35 cycles of 94°C for 30 seconds, 55°C for 30 seconds, and then 72°C for 30 seconds, followed by 72°C for 7 minutes-1 cycle. These PCR conditions were used for all PCR amplifications, unless otherwise indicated.

In addition, $\alpha 7$ -specific primer sets were used to identify the two PAC clones 64a1 and 25919. A Research Genetics BAC library was screened with $\alpha 7$ coding region primers by PCR to identify the BAC clone 467o18. The BAC library purchased from Research Genetics was a "pooled DNA" library, with each hit-positive PCR product of correct size being indicative of a location on a subsequent plate of pools. A hit on this plate gave an address to yet another plate, where the clone of interest was found. These "BAC clone" plates are maintained by Research Genetics. When the positive PCR reactions produced a final plate address in the clone library, that clone was ordered from Research Genetics. The PCR conditions and primers were as described herein (the primers used are shown in Tables 1 and 2). The two PAC clones (64a1 and 25919) were identified using the following PCR primers.

The primers used in these experiments were:

sense	TCCTGATGTCGGCTCCCAACT	(SEQ ID NO:1)
antisense	GGTACGGATGTGCCAAGGATA	(SEQ ID NO:2)
sense	TTTGGGGGTGCTAATCCAGGA	(SEQ ID NO:3)
antisense	TTGTTTTCCTTCCACCAGTCA	(SEQ ID NO:4)
sense	CTCGCTGCAGCTCCGGGACTCA	(SEQ ID NO:5)
antisense	GGAGGCTCAGGGAGAAGTAG	(SEQ ID NO:6)

The first two sets of primers were used to amplify the 3' untranslated region of the gene and the third primer set was used to amplify the first and second exons of the gene with the intervening intron 1 sequence. All PCR reactions were optimized in a Perkin Elmer 480 PCR using normal human DNA and cDNA. Conditions were as follows for the control reactions in the 3' sets: 96°C for two min, then 35 cycles of

96°C for 30 sec, 56°C for 30 sec, 72°C for 1 min, and cool to 4°C, using 4 mM MgCl₂ and 10% DMSO. The 5' PCR set was used in 1.5 mM MgCl₂ and 10% DMSO with the following conditions: 96°C for 3 min, then cycles 1-6 were 94°C for 1 min, 68°C - 58°C for 1 min (dropping from 68°C to 58°C, by 2°C increments each cycle), 72°C for 1 min, followed by 30 cycles of 94°C for 1 min, 58°C for 1 min, 72°C for 1 min, then a 4 min extension at 4°C, followed by chilling at 4°C.

In these experiments, a genomic clone for the human $\alpha 7$ nicotinic receptor was identified. A YAC designated as b134h10 of approximately 250 kb, was isolated from the St. Louis YAC library. A Southern blot comparison of YAC b134h10 with human genomic DNA indicated that it contained the full length $\alpha 7$ nAChR gene. This YAC was used to isolate a polymorphic marker, D15S1360, as described in greater detail below.

The polymorphic marker D15S1360, a complex microsatellite with four alleles, was isolated from a YAC containing the $\alpha 7$ nicotinic receptor gene. The Genbank sequence for rat $\alpha 7$ (#M85273) was used to design primers to the conserved regions of the $\alpha 7$ coding sequence. These primers were then used to PCR amplify normal human hippocampal cDNA obtained from a normal brain postmortem. The products were sequenced by Automated dye-terminator chemistry (as described in Example 5). The human sequence in transmembrane regions III and IV was then used to design PCR primers. These primers were: 5'-CTC CAG GAT CTT GGC CAA GTC-3' (sense strand; SEQ ID NO:7), and 5'-AGA TGC CCA AGT GGA CCA GAG-3' (antisense strand; SEQ ID NO:8).

The PCR reactions were conducted with 2 mM MgCl₂ and 10% DMSO, in a Perkin-Elmer 4800 using the following cycles: 94°C for 2 min, then 5 cycles of 94°C for 1 min, 56°C for 30 sec, 72°C for 1 min, then 35 cycles 94°C for 1 min, 54°C for 30 sec, 72°C for 1 min, and cooling at 4°C. The product was reamplified with primers extended to contain a sense *Xba* and antisense *Bam* site. The products were cut and ligated into a BlueScript SK- vector. Sequence of the probe was confirmed by automated dye-primer sequencing. Subsequent PCR based screening of the original

YAC clones were based on the above primers and conditions, substituting YAC DNA for hippocampal cDNA as the template.

The PCR fragment (*i.e.*, the probe) was sequenced and human primers were designed to generate a 338 bp product, which was cloned into pBluescript SK(-). The sequence of the 338 bp probe was:

AGATGCCCCAAGTGGACCAGAGTCATCCTTCTGAACTGGTGC GCGTGGTTCCT
GCGAATGAAGAGGCCCGGGGAGGACAAGGTGCGCCCGGCCTGCCAGCACAA
GCAGCGGCGCTGCAGCCTGGCCAGTGTGGAGATGAGCGCCGTGGGCCCCGCCG
CCCGCCAGCAACGGGAACCTGCTGTACATCGGCTTCCGCGGCCTGGACGGCG
TGC ACTGTGTCCCGACCCCCGACTCTGGGGTAGTGTGTGGCCGCATGGCCTGC
TCCCCACGCACGATGAGCACCTCCTGCACGGCGGGCAACCCCCCGAGGGGGG
ACCCGGACTTGGCCAAGATCCTGGA (SEQ ID NO:9).

This probe was used to isolate a human $\alpha 7$ cDNA (GenBank #U40583). The Washington University human YAC library was screened with the same primers. Two clones were isolated, B132H10 (150 kbp) and B134H10 (300 kbp), on the TAFE (Beckman) gel system, using the procedures recommended by the manufacturer.

A sub-library of B134H10 was prepared in the λ ZAP phagemid vector by complete *Mbo*I digestion of the intact YAC DNA in a low-melt agarose plug. The DNA was extracted and ligated into *Bam*HI digested and phosphatased vector, transformed into XL1Blue-(MRF'), and screened with a (CA)₁₆ (SEQ ID NO:10) oligonucleotide. One clone contained a microsatellite [(CA)₅T(CA)₁₂TA(CA)₅C(CA)₃] (SEQ ID NO:11), which mapped to chromosome 15 (Human/Rodent Hybrid Mapping Panel #1, Coriell, Camden NJ). Flanking primers amplified seven additional alleles (97, 107, 109, 111, 113, 115, and 117 bp). The primers used were 5'-GATCTTTGGTAGAAGC-3' (SEQ ID NO:12), and 5'-ACCACCACTACCATACAGAC-3' (SEQ ID NO:13). Allele frequencies (0.006, 0.006, 0.006, 0.516, 0.370, 0.090, and 0.006; heterozygosity 0.57) were estimated from individuals marrying into the pedigrees described in Example 1. Primer sets used for mapping $\alpha 7$ exons to YAC clones are listed in Table 1, below. Primers used for mapping STS/dinucleotide repeat markers to YAC clones were obtained from

Genbank, and are listed in Table 2. In these Tables, and unless otherwise indicated, all DNA sequences are shown in 5' to 3' orientation.

Table 1. Primer Sets Used to Amplify Exon and Flanking Intron Sequence from Human Alpha-7 Nicotinic Receptor

Sequence Amplified and Primer Number	Sequence	SEQ ID NO:
Promoter #1234	CAAAGAACGCAAGGGAGAGGT	SEQ ID NO:14
Promoter #1235	CGGCTCGCGCGCCTTTAAGGA	SEQ ID NO:15
Exon 1 #1331 or #1236	GGGCTCGTCACGTGGAAAAGC	SEQ ID NO:16
Exon 1 #1233	GGATCCCACGGAGGAGTGGAG	SEQ ID NO:17
Exon 2 #1198	CCTGCCCCGGGTCTTCTCTCCT	SEQ ID NO:18
Exon 2 #1138	AACTAGAGTGCCCCAGCCGAGCT	SEQ ID NO:19
Exon 3 #1475	AACAACGCTCTCGACAGTCAGATC	SEQ ID NO:20
Exon 3 #1476	AAGATCTTGCAGCCCATGGGAG	SEQ ID NO:21
Exon 4 #1368	GGAATTCTCTTTGGTTTTGCAC	SEQ ID NO:22
Exon 4 #1369	ACATATCCAGCATCTCTGTGA	SEQ ID NO:23
Exon 5 #1218	TCATGCAGTCCTTTTCCTGTTTC	SEQ ID NO:24
Exon 5 #1142	CTCGCTTCAGTTTTCTAACATGG	SEQ ID NO:25

**Table 1. Primer Sets Used to Amplify Exon and
Flanking Intron Sequence from Human Alpha-7
Nicotinic Receptor**

	Sequence Amplified and Primer Number	Sequence	SEQ ID NO:
	Exon 6 #1124	GGAAGTGTGTGTATTTTCAGC	SEQ ID NO:26
	Exon 6 #1144	TTAAAGCTTGCCCAGGAATAGG	SEQ ID NO:27
5	Exon 7 #1143	GCTTGTGTGTGGTATACACATTG	SEQ ID NO:28
	Exon 7 #1126	TCCAGAGCTGATCTCAGCAGAAG	SEQ ID NO:29
10	Exon 8 #1125	GCCCCTCGTTAGACAGAATTGAG	SEQ ID NO:30
	Exon 8 #1145	CTGGGCACACTCTAACCCTAACC	SEQ ID NO:31
	Exon 9 #1146	TGTGACGTGCAGTGCCACAGGA	SEQ ID NO:32
15	Exon 9 #1127	AAAACCCTAGGAGGAGCCTCCTT	SEQ ID NO:33
	Exon 10 #1128	GATCAGCCCGTTTCCGCCTCA	SEQ ID NO:34
20	Exon 10 #589	GGTACGGATGTGCCAAGGATA	SEQ ID NO:35
	Exon A #1516	GGACTCTGCTTTTGATAAATATGTA TG	SEQ ID NO:36
	Exon A #1517	TTGCTGTCACTTTCTGTGTTTCAT	SEQ ID NO:37
25	Exon B #1283	GACAATCCAAAGGTGCAGAAAGC	SEQ ID NO:38
	Exon B #1538	TTCGTATCTGTATACAGACAGTC	SEQ ID NO:39

**Table 1. Primer Sets Used to Amplify Exon and
Flanking Intron Sequence from Human Alpha-7
Nicotinic Receptor**

Sequence Amplified and Primer Number	Sequence	SEQ ID NO.
Exon C #1567	CCTCAGCATCATATTAGTTCAGTG	SEQ ID NO:40
Exon C # 1572	GCGGACAAGAGAAACAGGAAAG	SEQ ID NO:41
Exon D #1534	GGCAGTGGTGCTGTTGCCCTT	SEQ ID NO:42
Exon D #1568	TTTCTCCTGGGACTCTGGGCAC	SEQ ID NO:43

Table 2. STS/Dinucleotide Repeat Markers

Marker	Genbank Accession #
D15S942	G04933
D15S1043	Z51622
D15S165	Z17271
D15S1031	Z51346
D15S1010	Z53401
D15S144	Z23286
D15S1007	Z53384
D15S995	Z53051
D15S1040	Z51533

Additionally, genomic P1 artificial chromosome (PAC) clones for $\alpha 7$ were obtained from Genome Systems. PAC-64-A1 is 120 kbp long and contains both D15S1360 and the 5' end of the coding region. L76630 was localized in a genomic fragment containing the $\alpha 7$ nicotinic receptor gene (CHRNA7), isolated from a human genomic library (Stratagene), by screening with a human $\alpha 7$ cDNA clone (HP411).

A 6 kbp *EcoRI* genomic fragment was identified, partially sequenced, and found to include a CA dinucleotide repeat 3' of the last exon (GenBank #L76630). Flanking primers amplified 3 alleles (180, 178, 176 bp); allele frequencies were 0.06, 0.62, 0.32, with heterozygosity 0.51.

5 PCR was performed with 1.5 mM $MgCl_2$; 94°C for 5 min, 20 cycles of 94°C for 1 min, 56°C for 2 min, 72°C for 1 min and 72°C for 5 min. The two polymorphisms were genetically mapped in 96 individuals from 6 reference families (Centre d'Etude du Polymorphisme Humain). These reference families were selected because they have three generations of individuals available for genotyping. Their DNA is available
10 for genetic localization of markers, but their identities are confidential.

EXAMPLE 3

Generation of Templates for Sequence Analysis of the Intron/Exon Borders.

15 In this Example, extra-long PCR (XLPCR), originally described by Barnes (Barnes, Proc. Natl. Acad. Sci., 91:2216 [1994]), was conducted using *rTth* polymerase with the Perkin Elmer XL/PCR kit (Perkin-Elmer), on a PTC 200 (MJ Research) thermal cycler with the following conditions: 94°C, 1 min, 1 cycle; 94°C, 15 sec/68°C, 10 min, 16 cycles; 94°C, 15 sec/68°C, 10 min 15 sec, 12 cycles; 72°C, 10 min, 1 cycle. Enzyme, primer concentration, and dNTP concentrations were as recommended by the
20 manufacturer. A sublibrary of YAC b134H10 was constructed by *EcoRI* digestion and subcloning into Bluescript (SK-), (Stratagene), for splice junction determination on the larger introns.

25 To characterize the promoter and borders around exon 1 and 2, an *EcoRI* and *KpnI* sublibrary of PAC 25919 was constructed in Bluescript (SK-). A 2.9 kb clone containing exon 1, and a 5 kb clone containing exon 2 were identified by screening the PAC sublibrary by hybridization with an $\alpha 7$ cDNA subclone containing 90 bp of 5' untranslated sequence, exon 1 and exon 2.

Tentative exon borders were deduced based upon the organization of the $\alpha 7$ nAChR gene in the chick (Couturier *et al.*, Neuron 5:847 [1990]). Oligonucleotide primers, as shown in the table below, were designed from within the predicted exons that would amplify across the putative introns using extra-long PCR (XLPCR) with both genomic DNA and YAC b134h10 DNA. The exon primers used were as follows. For exon 5 to exon 10, the primers used were Primer #661 (TGACGCCACATTCCACACTAA)(SEQ ID NO:44); and Primer #591 (TTGTTTTTCCTTCCACCAGTCA)(SEQ ID NO:45). These primers amplify introns 5,6,7,8,and 9, with an approximate size of 14 kb. For exon 3 to exon 4, the primers used were Primer #1019 (CCAAGTTTAAACCACCAACATTTGG)(SEQ ID NO:46); and Primer #1020 (TCCCCGCGGAAGAATGTCTGGTTTCCAAATCTG)(SEQ ID NO:47). These primers amplify intron 3, with an approximate size of 8 kb.

The majority of intron-exon borders were determined from sequencing the XLPCR products. XLPCR products were not generated between exons 2 and 3 and between exons 4 and 5, suggesting that these introns are large. Preliminary Southern blot data suggested that both are > 25 kb. The intron 2 acceptor border, and the intron 4 donor and acceptor borders were determined after sequencing *EcoRI* subclones derived from YAC b134h10. The intron 2 donor was determined from sequencing a *KpnI/EcoRI* fragment, subcloned from PAC 25919. Exon/intron border sequence and approximate lengths for introns and exons are summarized in Figure 1. All of the identified intron-exon borders are consistent with 5' donor and 3' acceptor RNA splice site consensus sequences.

The organization of the human $\alpha 7$ nAChR gene was found to be identical to that found in chick with respect to number and size of exons. A signal peptide sequence predicted by homology with the rat $\alpha 7$ and muscle $\alpha 1$ coding sequences (*See e.g.*, Séguéla *et al.*, J. Neurosci., 13:596 [1993]; Conti-Tronconi *et al.*, Proc. Natl. Acad. Sci. 82:5208 [1985]; and von Heijne, Nuc. Acids Res., 14:4683 [1986]) was found to be encoded by exon 1. Putative glycosylation sites (*See e.g.*, Séguéla *et al.*, *supra*; Schoepfer *et al.*, Neuron 5:35 [1990]) were found in exons 2, 4 and 5. Cysteine

residues that form a putative disulfide bridge (Galzi *et al.*, Ann. Rev. Pharmacol., 31:37 [1991]) were found to be encoded by exon 6. The vicinal cysteines at the acetylcholine (ACh) binding site, the α -bungarotoxin binding site, and membrane spanning region I, are all coded by exon 7. Membrane spanning regions II and III, as
5 in the rat, were found to be coded for by exons 8 and 9 respectively, and membrane spanning region IV was found to be encoded by exon 10.

The putative promoter, and the borders for exons 1 and 2 were determined from sequencing *KpnI* and *EcoRI* subclones derived from PAC 25919, which contains exons 1-3 and sequences 5' of the coding region. A 2.9 kb *EcoRI-KpnI* fragment contained
10 2.6 kb of the region 5' of exon 1, exon 1 and 200 bp of intron 1. Sequence analysis indicated that 392 bp of the 5' region (GenBank #AFO29837), shown in Figure 4, is 77% GC rich and lacks a consensus TATA box sequence. In this Figure, the nucleotides are numbered relative to the ATG translation initiation site (indicated with Met); the coding sequence is indicated in bold. Consensus AP-2, Sp1, and CREB
15 sequences are shown in boxes. Alignment of the chick (Matter-Sadzinski *et al.*, EMBO J., 11:4529 [1992]) and human promoter sequences indicate they share only 52.9% homology. However, consensus Sp1, and AP-2 transcription factor binding sites are present in both human and chick $\alpha 7$ promoters at approximately the same location, relative to the start of translation (Matter-Sadzinski *et al.*, *supra*). A CREB
20 consensus binding sequence is present in the human promoter, but is not found in the chick.

The primers listed in Table 1 provide a means to obtain sequence information from genomic DNA. Using sequencing techniques standard in the art (*e.g.*, including, but not limited to standard dideoxy sequencing, chain termination sequencing using *Taq*
25 DNA polymerase or other thermostable polymerases, and automated processes that use these and other technologies), the sequences near the intron and exon junctions can be obtained. Such primers have been successfully used to obtain sequence information from blood samples obtained from schizophrenic patients (*i.e.*, samples obtained as described in Example 1). Sequence obtained from this portion of the chromosome also

finds use in providing linkage signal for other nicotine-dependent illnesses including, but not limited to, small cell lung cancer and juvenile myoclonic epilepsy. These sequences are then analyzed to determine if they contain pathogenic mutations that alter gene function by changing the amino acid coding, or by altering gene expression or response to promoter molecules, or by introducing variations in gene splicing. These mutant sequences are also expressed in transgenic cells in culture or in transgenic mice or in frog oocytes, to determine if they indeed cause altered gene function that produces heritable human illnesses such as schizophrenia.

EXAMPLE 4

Identification of Expressed Sequence Tagged cDNAs

In this Example, expressed sequence tagged (EST) cDNA clones were identified in the EST Database at the National Center for Biotechnology Information (NCBI), Bethesda, MD, by BLAST homology searches using $\alpha 7$ cDNA specific sequences. Two (EST 3952 and EST 52861) were purchased from Research Genetics and sequenced bi-directionally as described in Example 5. Contigs were constructed using Sequencher software (Gene Codes).

EXAMPLE 5

Sequence Analyses and Restriction Mapping

In this Example, sequences were determined using standard sequencing kits and automated sequencing. In addition, genomic DNA probed with portions of $\alpha 7$ cDNA was used to order *HindIII* restriction fragments.

Hand Sequencing

PCR product for hand sequencing was prepared using the Exonuclease I-Shrimp Alkaline Phosphatase reagent pack (Amersham), per the manufacturer's directions. Sequencing was done using Thermo Sequenase Radiolabeled Terminator Cycle
5 Sequencing Kit from Amersham. The manufacturer's recommended component concentrations were used with 10 ng of template per 250 bp product per reaction. Reactions were run on a BioRad Sequi-Gene GT sequencing system (BioRad), using a 6% acrylamide/bisacrylamide (19:1) gel.

10 Automated Sequencing

Plasmids to be sequenced were colony purified, using a Qiagen kit (Qiagen). PCR products from PACS, BACs, and YACs were gel purified using a Qiagen PCR product gel extraction protocol. Automated sequencing (ABI 373 or 377, Perkin Elmer) was conducted using Perkin Elmer ABI Dye Terminator or M13 Dye Primer kits, following
15 manufacturer's protocols. Sequencing was organized into contigs using the Sequencher program (Gene Codes). All sequencing was bi-directional.

Restriction Endonuclease Mapping

Southern analysis of genomic DNA probed with portions of $\alpha 7$ cDNA was used to order *HindIII* restriction fragments (Dracopoli *et al.*, *supra*). DNA was transferred to
20 Hybond N+, and hybridized at 40°C in 5X Denharts (0.5% SDS, 6X SSC and 50% formamide), then washed twice in 0.1% SDS and 0.1X SSC at 65°C for 10 minutes.

EXAMPLE 6

Large Insert Clone Contig

Total yeast DNA was isolated from YAC-bearing yeast using a spheroplast method
25 (Dracopoli *et al.*, *supra*). Loci in and around the $\alpha 7$ region were PCR amplified with loci specific primers (*i.e.*, primers shown in Table 2, as well as primers for D15S1360

described in Example 2). PCR was performed with 1.5 mM MgCl₂: 94°C for 5 min, 20 cycles of 94°C for 1 min, 56°C for 2 min, 72°C for 1 min and 72°C for 5 min.

Mapping of specific exons was performed using the primers listed in Table 1 and the PCR conditions were 94°C for 2 minutes, 1 cycle; followed by 35 cycles of 94°C for 30 seconds, 55°C for 30 seconds, and then 72°C for 30 seconds, followed by 72°C for 7 minutes-1 cycle.

Specific amplification was confirmed by sizing the products on agarose gel. PCR products from $\alpha 7$ exons were excised from the gel, Qiagen extracted (Qiagen), and sequenced as described in Example 5.

Additional large insert genomic clones were isolated by PCR screening with $\alpha 7$ -specific primers (Chumakov *et al.*, *supra*). YACs 953g6, 948a10, 853b12, and 969b11 were isolated from the CEPH YAC Library 3. PAC clones 64a1 and 259I9 were identified by Genome Systems and BAC 467o18 was identified in a BAC library purchased from Research Genetics.

A tentative YAC contig was designed from markers in the YACs and information in the CEPH/Genathon Database. YACs providing linkage between the full-length and duplicated $\alpha 7$ gene sequences, YACs 895f6, 776a12, 791e6, 811b6, 859c11, 801e1, 810f11, 966a4, 764f8, and 822g2, were obtained from Research Genetics. The contig, shown in Figure 5, was verified by PCR and sequencing of either $\alpha 7$ sequence or published marker sequence. Loci from the 15q13-14 region were assigned to YACs, BACs, and PACs. The results confirmed the presence of markers previously assigned by Genethon (Human Genome Research Center; a publicly accessible database that maintains human genome linkage information). As indicated in Figure 5, two allele sizes for the L76630 loci were identified, suggesting that YAC 969B11 spans both $\alpha 7$ nAChr loci.

Exons 5-10 of the $\alpha 7$ nAChR gene and the polymorphic marker L76630 map to two distinct regions of the contig, suggesting a partial gene duplication. The distal, and full-length, $\alpha 7$ nAChR gene maps close to D15S1360, as indicated by two PAC clones (64a1 and 259I9) and one BAC clone (467o18). Both of these PACs, approximately 120 kb in size, contain the marker D15S1360 which was used to

demonstrate linkage of this region at 15q14 to a schizophrenic trait. Physical mapping of the $\alpha 7$ gene <120 kb from the linkage marker suggested that the $\alpha 7$ nicotinic receptor gene is an excellent candidate gene for this trait. The proximal duplicated exon sequences 5-10 of the $\alpha 7$ nAChR gene map between D15S1043 and D15S165.

5 The order of loci was determined to be D15S942, D15S1043, followed by the duplicated sequences L76630, exon 10, exon 9, exon 8, exon 7, exon 6, and exon 5, and then D15S165 and D15S1031. The closest marker flanking the 3' end of the $\alpha 7$ nAChR gene could not be established and is either D15S1031 or D15S1010. Thus, the full-length gene with the 3'-end closest to D15S1031 has been tentatively oriented,
10 based on the confirmed orientation of the duplicated sequences.

In order to determine if sequence differences were present that might distinguish duplicated exons 5-10 from the full-length gene, PCR products were generated and sequenced from 11 of the genomic YAC clones in the contig. Of these 11 clones, two (948a10 and 853b12) clearly mapped to the duplicated region between D15S1043 and
15 D15S165, and eight mapped to the full-length $\alpha 7$ nAChR gene region near D15S1360. All of the $\alpha 7$ exons were found to be present in YACs 776a12, 791e6, 811b6, 953g6, b134h10, 859c11, 810f11 and 801e1. YAC 948a10 contained only exons 5-10, and 853b12, 6-10, while YAC 969b11 appeared to contain both loci. This YAC is 1.03 Mb in size (Figure 5), suggesting that the full-length $\alpha 7$ gene and duplicated sequences are
20 not more than 1 Mb apart.

Sequence variants found in DNA from duplicated and full-length genomic $\alpha 7$ sequences are shown in Figure 2. In exon 6, a 2 bp deletion was identified at bases 497-498 (TG) in clones from the duplicated region, which results in a frame shift in the coding sequence and the insertion of a stop codon within the exon.

25 Additional sequence variants were found at bases 654, 793, 1269 and 1335 of the coding region. These are conservative base changes that do not change an amino acid. The polymorphic marker, L76630 is also duplicated as evidenced by the presence of a different number of CG repeats in the 3'UT of the full length $\alpha 7$ gene and the 3' sequences following exon 10 in the duplicated sequences. YAC 969b11, which

contains both full length and duplicated sequences also has two copies of L76630 as does a chromosome 15 hybrid, R379-2B2 (Figure 2).

EXAMPLE 7

RACE Analysis

5 In this Example, amino terminal clones for the human $\alpha 7$ subunit were obtained by 5' RACE (*i.e.*, Rapid Amplification of cDNA Ends) (Frohman, Amplifications 5:11 [1990]), using a kit from Gibco-BRL, with some modifications. Although some of these products had the amino terminus nucleic acid sequences that were expected by homology with chicken and rat sequences, some had novel sequences that revealed the
10 presence of unsuspected alternative exons. The present invention provides, for the first time, the sequences of these exons and their location in the genomic structure of $\alpha 7$.

Total RNA was isolated from normal human hippocampus by the method of Chomczynski and Sacchi (Chomczynski and Sacchi, Anal. Biochem., 162:156 [1987]). Briefly, brain tissue from the human hippocampus was disrupted in the presence of
15 Solution D (4 M guanidium thiocyanate, 25 mM sodium citrate (pH 7.0), 5 % sarcosyl, 0.1 M 2-mercaptoethanol) in a tissue homogenizer. The homogenized tissue was acidified with 0.1 X volume of 2 M sodium acetate, pH 4.0, with "X" referring to the initial volume of Solution D. The acidified tissue homogenate was extracted with 1 X volume of water-saturated phenol and 0.2 volume of chloroform:isoamyl alcohol
20 (49:1). The phases were separated by centrifugation (the supernatant contains RNA whereas the DNA and proteins remain in the interphase and the phenol). The RNA was precipitated by adding an equal volume of isopropanol (20°C), centrifuged and the pellet resuspended in 1 mM EDTA, pH 8.0. The concentration of the RNA was determined by measuring the absorbance at 260 and 280 nm.

25 The first strand cDNA synthesis for 5'-RACE was performed as indicated in the manufacturer's instructions, with the addition of methylmercuric hydroxide (7 mM) to reduce secondary structure. The cDNA was synthesized using a human gene-specific antisense oligonucleotide: 5'-AGGACCCAAACTTCAG-3' (SEQ ID NO:7),

complementary to 5'-sequence in the longest human clone from the primary cDNA screen. Following cDNA synthesis, terminal deoxynucleotide transferase was used to attach homopolymeric (dCTP) tails to the 3' ends of the cDNA. A nested gene specific antisense primer and an anchor primer from the 5'-RACE kit, both containing
5 triplet repeat sequences for annealing to the pAMP1 vector, were used for PCR amplification of a homopolymeric, tailed cDNA product. The sequences of the primers were: for the antisense primer,
5'-CAUCAUCAUCAUCCAGCGTACATCGATGTAGCAGGAACTCTTGAATAT-3'
(SEQ ID NO:49), and the anchor primer 5'-
10 CUACUACUACUAGGCCACGCGTCGACTAGTACGGGIIGGIIGGGIIG-3' (SEQ ID NO:50). In this anchor primer sequence, the "I" is inosine.

Briefly, the final composition of the PCR reaction for amplification of dC-tailed cDNA was as follows: 20 mM Tris-HCl (pH 8.4), 50 mM KCl, 1.5 mM MgCl₂, 400 nM for both primers, 200 μ M each dNTP, 8 % DMSO and 0.2 unit/ μ l *Taq* DNA
15 polymerase. The PCR program was as follows: 94°C, 1 min; 57°C, 30 sec; 72°C, 2 min for 35 cycles; final extension at 72°C for 10 min, then soak at 4°C.

PCR products were Glassmax (Gibco-BRL) purified and reamplified with the same reaction conditions using the following program: 94°C , 1 min; 50°C, 30 sec; 72°C, 2 min for 5 cycles; 94°C, 1 min; 55°C, 30 sec; 72°C, 2 min for 35 cycles; extension at
20 72°C for 7 min, and soak at 4°C. Products from this PCR reaction were then gel purified and cloned into the pAMP1 vector (Gibco-BRL) with uracil DNA glycosylase according to manufacturer's directions, for subsequent automated sequencing, as described in Example 5.

A group of novel exons located in YAC, PAC and BAC clones containing the full-
25 length gene and/or the duplicated α 7 sequences was also evidenced. These novel exons were discovered in the process of comparing RACE clones, isolated during cloning of the α 7 human cDNA, with EST cDNA clones (EST 3952 and EST 52861) found in the EST Database (NCBI) by homology screening. During cloning of the 5'end of the α 7 coding region, the RACE technique was used to amplify the 5'end of
30 the α 7 cDNA (Frohman, *supra*). Although cDNA clones which matched sequence for

published human $\alpha 7$ from a neuroblastoma cell line SH-SY5Y (Peng *et al.*, Mol. Pharm., 45:546 [1994]), were obtained, clones with 5' sequence that could not be identified were also obtained.

When EST cDNA clones were subsequently found in the EST database by
5 homology screening, several were identified that had exons 5-10 and unknown
sequence 5' of exon 5. Comparison of the 5' ends of the RACE and EST products
showed that the novel sequences are partially homologous. PCR primers were
designed to these novel sequences for amplification from genomic DNA. Intronic
10 sequence and consensus splice junctions that identified these sequences as four
alternatively spliced and previously unreported exons were then identified. The sizes
and splice junctions for these novel exons, designated as $\alpha 7D$, $\alpha 7C$, $\alpha 7B$, and $\alpha 7A$
are shown in Figure 6. In this Figure, the sequence of the RACE clone (Genbank
#AFO29838) is shown in uppercase, while intron boundaries are shown in lowercase,
and are not included in the nucleotide numbering. The sizes of the exons are indicated
15 below the exon designations. RACE clones, containing these novel exons were
previously deposited with GenBank (RACE D-C-B-A-5-6; AFO29838; RACE D-C-A-
5-6, Genbank; #AFO29839).

EXAMPLE 8

RT-PCR Analysis

20 Total RNA was isolated from normal human hippocampus, human cingulate gyrus,
the SH-SY5Y neuroblastoma cell line, and human immortalized lymphocytes with
TRIzol reagent (Gibco-BRL) following manufacturer's instructions. The mutations
seen in the PAC, BAC, YAC and published $\alpha 7$ sequences were screened in seven
normal subjects and SH-SY5Y cells. DNA was evaluated for all subjects, while
25 cDNA was evaluated in exons 1-10 and exons 5-10 for all subjects, and exons D-10
were evaluated in one normal subject and SH-SY5Y cells. The DNA and RNA were
obtained as detailed above. The cDNA was generated as previously detailed.

Total RNA was isolated from normal human hippocampus, human cingulate gyrus and SH-SY5Y neuroblastoma cell line by the TRIzol reagent (Gibco-BRL) following manufacturer's directions. RNA was stored as an ethanol precipitate until centrifugation and resuspended in 1 mM EDTA, pH 8.0 prior to cDNA preparation.

5 Total RNA was reverse transcribed at 42°C for 60 min in a 40 µl volume with Superscript II reverse transcriptase (Gibco-BRL) and random hexamer primers (Pharmacia). The final concentration of the components of the reaction were as follows: 1x first strand buffer (50 mM Tris-HCl, pH 8.3, 75 mM KCl, 3 mM MgCl₂), 1 mM dATP, 1 mM dGTP, 1 mM dCTP, 1 mM dTTP, 8 µM random hexamers, 10
10 mM DTT, 0.5 u/µl placental Rnase inhibitor (Boehringer-Mannheim), 2.5 u/µl Superscript II reverse transcriptase and 500 ng of total RNA.

Primary PCR of the exon 1-10, exon 5-10 and exon D-10 products was performed using the Advantage-GC cDNA PCR kit (Clontech). Briefly, 5 µl of RT products were diluted to 50 µl with 40 mM Tricine-KOH, pH 9.2 at 25°C, 15 mM KOAc, 3.5
15 mM Mg(OAc)₂, 5% DMSO, 3.75 µg/ml BSA, 0.2 mM of each dNTP, 0.2 µM of each primer, 1 M GC- Melt and 1x KlenTaq-1 DNA polymerase mix. Samples were incubated in a Perkin-Elmer 480 DNA Thermocycler.

For Exon 1-10, the sense primer was 5'-
CGCTGCAGCTCCGGGACTCAACATG-3' (SEQ ID NO:51), and the antisense
20 primer was 5'-TGCCCATCTGTGAGTTTTCCACATG-3' (SEQ ID NO:52). The PCR conditions were 94°C, 1 min; 5 cycles at 94°C, 30 sec, 72°C, 3 min; 5 cycles at 94°C, 30 sec, 70°C, 3 min; 25 cycles at 94°C, 20 sec, 68°C, 3 min; final extension at 68°C, 3 min and soak at 4°C.

For Exon 5 to 3'UT α7 transcript, the sense primer was 5'-
25 TGACGCCACATTCCACACTAA-3' (SEQ ID NO:53), and the antisense primer was 5'-CCCCAAATCTCGCCAAGC-3' (SEQ ID NO:54). The PCR conditions were 5 cycles at 96°C, 1 min, 50°C, 30 sec, 72°C, 1 min; 30 cycles at 95°C, 30 sec, 62°C, 20 sec, 72°C, 30 sec; final extension at 68°C, 3 min and soak at 4°C.

For Exons D-10, the sense primer was 5'-CTCGGTGCCCCTTGCCATTT-3' (SEQ
30 ID NO:55), and the antisense primer was 5'-CCTTGCCCATCTGTGAGTTTTCCAC-

3' (SEQ ID NO:56). The PCR conditions were 94°C 1 min, 5 cycles 94°C, 30 sec, 70°C, 3 min 5 cycles 94°C 30 sec, 68°C, 3 min, 25 cycles 94°C 20 sec, 66°C 3 min 1 cycle 68°C 3 min, cool to 4°C.

The products generated from exons 1-10, 5-10 and D-10 were further amplified to incorporate M13 primer sequences into products small enough to sequence in both directions. PCR conditions were as follows for all secondary, nested PCR amplifications. Perkin-Elmer Core reagents were used in standard concentrations using 2 mM MgCl₂, 0.1 mM each dNTP, 1.5 U *Taq* Gold, 10% DMSO and 25 pM of each primer in a 50 µL reaction. PCR reactions were heated at 96° for 5 min, then 5 cycles were performed at 96°C for 1 min, 60°C for 30 sec, 72°C for 1 min; then 30 cycles for 95°C for 30 sec, 68°C for 20 sec, and 72°C for 30 sec, followed by a 7 min 72°C extension and cooling at 4°C.

All cDNA reactions were performed in duplicate using 50 ng RNA equivalents in a primary reaction, encompassing the full cDNA length of interest, then reamplified in nested, secondary PCR reactions to incorporate M13 primers into shorter products. DNA amplifications were performed in duplicate from 100 ng of needle-sheared template, within exon boundaries. The duplicates were then pooled, Centricon 100 (Amicon) column purified and sequenced using standard M13 Dye Primer chemistry on an ABI 373 Automated sequencer. All templates were sequenced bi-directionally, except where sequence length did not allow a nested primer. Alternate splice products were hand called from the electropherograms. Clean sequences were aligned and checked with Sequencher Software (Gene Codes Corporation).

DNA products were generated with primer pairs 1552/1553, 1101/1102, 1097/1098 and 1099/1100 to check the 497-498 deletion, 654/690, and 1269/1335 mutations, respectively. These primers are shown in Table 3, below. In this Table, "1ry" and "2ry" refer to the first and second primer sets in nested PCR. The cDNA amplifications required three sets of primary amplifications, exons 1-10, exons 5-10 and exons D-10. Primer pair 1381/1382 was used to amplify exons 1-10; primers 1482/1483, 1101/1098 and 1099/1481 were then used as nested primers from this primary PCR to check 497-498, 654/693 and 1269/1335 respectively. The exon 5-10

product was amplified with primer pair 1502/1503, nested primers 1502/1483, 1101/1098 and 1099/1481 were used to check 497/498/654/693, 654/690-and 1269/1335 respectively. Exons D-10 were amplified with primers 1569/1562, and the nested primers 1553/1098 and 1097/1481 were used to check 497-498/654/690 and 1269/1335, respectively. Redundancy in the overlap of the secondary PCR products was used to double check some mutations, necessary when alternate splicing or base pair deletions occurred, making some base calls difficult.

Exon 3 codes for 15 amino acids near the amino terminal, in the extracellular domain. An alternate transcript without this exon appears in most PCR amplifications of this region, at a somewhat diminished concentration in comparison to the full-length transcript.

To determine if the exon 5-10 copy of $\alpha 7$ was expressed, a second RT-PCR product was generated, encompassing only exons 5-10. The bases which appeared to be heterozygous in the DNA, but which are not heterozygous in the exon 1-10 transcript, are now fully accounted for in the 5-10 exon product, showing the exon 5-10 gene to be expressing as cDNA. The base changes fall into three categories, those seen only in the full-length 1-10 transcript, those changes present only in the 5-10 transcript and bases changes seen in both transcripts.

The TG deletion at 497-498 is only present in the 5-10 transcript; the C at 654 can be assigned to the 1-10 transcript, the T to the 5-10 transcript; the G at 933 can be assigned to both transcripts with an A in some subjects' 1-10 transcript and at 1335 the T can be assigned to the 1-10 transcript. The base changes seen at 690 and at 1269 appear to be present in both copies of the gene. These data are consistent with the base changes seen in the YAC, PAC and BAC clones, and the assignment of each clone to the duplicated or original gene.

Table 3. Primer Sequences

	Primer Number and Description	Sequence	SEQ ID NO.
5	1097 sense m13fwd+	CCCAGTACTTCGCCAGCACCATGAT	SEQ ID NO:57
	1098 antisense m13rev +	CCCCGTCGGGGTCGTGGTGGTGGTA	SEQ ID NO:58
10	1101 sense m13fwd+	TCCCCGGCAAGAGGAGTGAAAGGTT	SEQ ID NO:59
	1102 antisense m13rev +	ACACCAGCAGGGCGAGGGCGGAGAT	SEQ ID NO:60
15	1099 sense m13fwd+	GACCAGAGTCATCCTTCTGAACTGG	SEQ ID NO:61
	1100 antisense m13rev +	TTTCAGGTAGACCTTCATGCAGACA	SEQ ID NO:62
	1553 sense m13fwd+	CGATGTACGCTGGTTTCCCTTTGAT	SEQ ID NO:63
25	1552 antisense m13rev +	TTCCCACTAGGTCCCATTCTCCATT	SEQ ID NO:64
	1382 sense lry cDNA	CGCTGCAGCTCCGGGACTCAACATG	SEQ ID NO:65
30	1381 antisense	TGCCCATCTGTGAGTTTCCACATG	SEQ ID NO:66
35	1502 sense lry cDNA	TGACGCCACATTCCACACTAA	SEQ ID NO:67

Table 3. Primer Sequences

Primer Number and Description	Sequence	SEQ ID NO:
1503 antisense	CCCCAAATCTCGCCAAGC	SEQ ID NO:68
1569 sense lry cDNA	CTCGGTGCCCCTTGCCATT	SEQ ID NO:69
1562 antisense	CCTTGCCCATCTGTGAGTTTTCCAC	SEQ ID NO:70
m13 sense extension	TGTAACGACGGCCAGT	SEQ ID NO:71
m13 antisense extension	CAGGAAACAGCTATGACC	SEQ ID NO:72
1482 sense m13fwd+ 2ry cDNA	AAGGAGCTGGTCAAGAACTACAATC	SEQ ID NO:73
1483 antisense m13rev+	CCGGAATCTGCAGGAAGCAGGAACA	SEQ ID NO:74
1101 sense m13fwd+ 2ry cDNA	TCCCCGGCAAGAGGAGTGAAAGGTT	SEQ ID NO:59
1098 antisense m13rev +	CCCCGTCGGGGTCGTGGTGGTGGTA	SEQ ID NO:58
1502 sense 2ry cDNA	TGACGCCACATTCCACACTAA	SEQ ID NO:67
1483 antisense m13rev+	CCGGAATCTGCAGGAAGCAGGAACA	SEQ ID NO:74

Table 3. Primer Sequences

Primer Number and Description	Sequence	SEQ ID NO:
1553 sense m13fwd+ 2ry cDNA	CGATGTACGCTGGTTTCCCTTTGAT	SEQ ID NO:63
1098 antisense m13rev +	CCCCGTCGGGGTCGTGGTGGTGGTA	SEQ ID NO:58
1097 sense m13fwd+ 2ry cDNA	CCCAGTACTTCGCCAGCACCATGAT	SEQ ID NO:57
1481 antisense m13rev+	CCAGGCGTGGTTACGCAAAGTCTTTG	SEQ ID NO:75
1099 sense m13fwd+ 2ry cDNA	GACCAGAGTCATCCTTCTGAACTGG	SEQ ID NO:61
1481 antisense m13rev+	CCAGGCGTGGTTACGCAAAGTCTTTG	SEQ ID NO:75

An RT-PCR product was generated from exon $\alpha 7D$ to exon 10 from one normal brain and from SH-SY5Y cells. The resulting cDNA product contained alternate splice products with exons shown in Figure 2. The 2 base pair deletion seen at bases 497-498 in the DNA that is not present in the exon 1-10 transcript was seen in the D-10 transcript, while all of the D-10 product in SH-SY5Y was deleted at 497-498, and subject SL061 was heterozygous for the deletion in the D-10 product. The presence of the T at base 757 connects this base change to the TG deletion. The G at 690 was not expressed in either cDNA. The A at 933 was not present in the minus TG strand of SH-SY5Y. The T at 1296 was expressed in subject SL061. These

products, in subject SL061 cannot differentiate between the exon 5-10 product splicing to exon D versus exon 1, however the product in D-10 from SH-SY5Y can, since only the minus TG strand was expressed, negating the possibility that exons 5-10 from the 1-10 gene are splicing to exon D.

5 These new exons have been designated as 3' α 7A, α 7B, α 7C, α 7D 5'. The RACE products were variable in their inclusion of Exon B, similar to the EST clones. However, PCR products including exons D-10 gave many alternate splice products between exons D, C, B, 5 and 6. This same phenomenon was seen in the exon 1-10 transcripts between exons 2 and 6. Based on these results, it was not possible to fully
10 evaluate whether any of the D-10 transcript contain only exons 5-10 from the duplicated region or if this transcript contains some splicing of 5-10 from the 1-10 full gene sequence, since the cell line and the brain gave differing results. Subcloning is used to fully evaluate the base changes to separate the various splice products.

 These results indicate that the primer sequences described herein can be
15 successfully used to screen both genomic DNA and mRNA for the presence in DNA and the expression in mRNA of sequences which are polymorphic (*i.e.*, different) between individuals. Standard automated and hand sequencing methodologies are used to locate differences in samples obtained from individuals. It is contemplated that some of these polymorphisms, as well as others, have pathogenic roles. These
20 polymorphisms are also used to relate the inheritance of specific alleles of α 7 genes through families to the presence of illness or physiological dysfunction, using standard methods known in the art for linkage analysis.

EXAMPLE 9

Single Strand Conformation Polymorphism (SSCP) Analysis

PCR products, <200 bp, containing a single sequence variant were amplified with ³³Pγ-ATP kinased primer sets using Promega T4 kinase as known in the art (See e.g., Dracopoli *et al.*, *supra*). The primers used in this Example were:

Table 4. Primers Used for SSCP Analysis

Exon and Primer Number	Sequence	SEQ ID NO:
Exon 6b #1243	GATGTGCAGCACTGCAAACAA	SEQ ID NO:76
Exon 6b #1144	TTAAAGCTTGCCCAGGAATAGG	SEQ ID NO:77
Exon 6d #1124	GGAAGTGTGTGTATTTTCAGC	SEQ ID NO:78
Exon 6d #1245	AAGACCAGGACCCAAACTTGT	SEQ ID NO:79
Exon 7d #1143:	GCTTGTGTGTGGTATACACATTG	SEQ ID NO:80
Exon 7 #675	GTAGAGTGTCTGCGGC	SEQ ID NO:81
Exon 10 (1438) #672	GGTCCGCTACATTGCCAA	SEQ ID NO:82
Exon 10 #593	TGATGGTGAAGACCGAGAAGG	SEQ ID NO:83

Products, denatured with loading dye (7.26 M urea, 60% formamide, 22 mM EDTA, 32 mM NaOH, 0.25% bromophenol blue, 0.25% xylene cynol), were analyzed

on GeneAmp detection gels (Perkin Elmer) run at both 6°C and 25°C, using Bio Rad PowerPac 3000 with a temperature probe, as described by the manufacturer.

Thus, the frequency of these sequence variants was examined, using SSCP in a group of 43 normal control subjects with no history of mental illness. Primer sets derived from the exon and intron-exon boundary sequences are used to amplify 200 bp portions of the gene from individuals with schizophrenia and their relatives, in order to identify sequence changes that affect gene function. Sequence changes that are not known to affect gene function, but can serve as markers to trace heritability of particular gene regions through families, are also identified in this process. The -2 bp deletion and the heterozygosities at 654, 690, 1269, at 1335 were found in this Example.

Almost all subjects were heterozygotic at positions 654 and 690. Nucleotide positions 1269 and 1335 were also found to be polymorphic, suggesting that the duplicated sequences have diverged since the duplication event.

These results indicate that the primer sequences described herein can be successfully used to screen genomic DNA in SSCP, a standard genome screening technique, for polymorphic differences in DNA sequences between individuals. It is contemplated that these polymorphisms, as well as others, have pathogenic roles. These polymorphisms are also used to relate the inheritance of specific alleles of $\alpha 7$ genes through families to the presence of illness or physiological dysfunction, using standard methods known in the art for linkage analysis.

EXAMPLE 10

Electrophysiological Recording,

Linkage Analysis,

and Nonparametric Methods

Electroencephalographic activity was recorded at the vertex and electrooculographic activity was recorded from the superior orbital-lateral canthus. Five averages of sixteen responses each to paired clicks were obtained, using standard

methods (See, Griffith *et al.*, Psychophysiology 32:460 [1995], for the specific technique). The P50 responses were distinguished from pre-stimulus activity for both normals and schizophrenics at a high level of significance ($P < 0.001$). The averages were reviewed by two investigators, blind to genetic information, who rejected any average containing excessive electrooculographic activity, drowsiness, startle, or other artifacts; the remainder were combined into a grand average, from which the P50 amplitudes were measured and their ratio (second response/ first response) was calculated automatically by a computer algorithm (Nagamoto *et al.*, Biol. Psychiat., 25:549 [1989]). Seven subjects were not used, because artifact-free averages could not be selected from their recordings. Recordings were initially performed, then repeated approximately three years later. The earlier recordings were reanalyzed for 2 subjects who were later deceased, for 10 subjects who refused repeat recording, and for 2 patients who were later on atypical neuroleptics, which can normalize the P50 ratio; other neuroleptic medication do not affect the phenotype (Nagamoto *et al.*, Biol. Psychiat., 40:181 [1996]).

Parameters for lod score analyses of P50 ratios were determined from the distribution of values in 43 unrelated normal individuals and 36 unrelated schizophrenic patients (Waldo *et al.*, Schizophr. Res., 12:93 [1991]) and from observations of the segregation of P50 ratios in the nine multiplex schizophrenic families (*i.e.*, the families described in Example 1). Elevated P50 ratios were defined as values greater than or equal to 0.50, which were found in 91% of the unrelated schizophrenics and 6% of the normals. Of the remaining unrelated schizophrenics, most had values between 0.41 and 0.49, a range therefore coded unknown for the linkage analysis. If this unknown range was extended to include values between 0.40 and 0.60, the results were changed substantially (*e.g.*, lod scores were decreased by an average of 0.54 across the markers in the 15q13-14 region due to the loss in information). For lod score analyses, frequency of a gene for abnormal P50 ratio was fixed at 0.05, penetrance for the normal genotype was fixed at 0.01, and penetrance for the abnormal genotypes was fixed at 0.8 (Coon *et al.*, Biol. Psychiat., 34:277 [1993]).

These parameters result in a morbidity for abnormal P50 ratio of 8.7% and a phenocopy rate among abnormal subjects of 10.4%. The FASTLINK version of the LINKAGE program was used to compute lod scores at various recombination fractions, Θ (Lathrop *et al.*, Proc. Natl. Acad. Sci., 81:3443 [1984]). No significant
5 heterogeneity was found using the HOMOG program (Ott, *Analysis of Human Genetic Linkage*, Johns Hopkins Univ. Press, Baltimore [1991]). The chance of false positive lod score results was determined using SLINK (Ott, Proc. Natl. Acad. Sci., 86:4175 [1989]); 1000 replicates of the pedigrees were simulated, assuming no linkage to the marker under analysis. Lod score analysis was performed for each replicate under the
10 dominant model; the highest score observed for D15S1360 and P50 under the assumption of no linkage was 1.87.

Sibling pair analysis was performed using the SIBPAL program (Elston, *SIBPAL, Statistical Analysis for Genetic Epidemiology*, Louisiana State Univ. Medical Center, New Orleans, LA, version 2.2 [1995]). Marker data were used to estimate the
15 proportion of alleles shared through a common ancestor (*i.e.*, identical by descent) for each possible sibling pairing within the linkage families. A test was performed to determine if the proportion of alleles shared was > 0.50 for abnormal/abnormal pairs. To calculate *P* values, 1000 replicates of the 9 families were simulated for each marker to determine empirical distributions. Degrees of freedom were adjusted
20 downward for non-independence when multiple pairings were used from the same sibship within a family.

A newly developed method, Nonparametric Linkage, uses information from all genotyped members of a pedigree to assess the extent of alleles shared identical by descent among all affected individuals. The resulting statistic is normalized by first
25 subtracting the expected sharing score under the null hypothesis of no linkage from the observed score and then dividing by the score variance under the null hypothesis. Thus the statistic is asymptotically distributed as a standard normal variable (*Z* score) under the null hypothesis. Calculations of Nonparametric Linkage statistics were carried out using the GENEHUNTER computer programs (Elston, *supra*).

GENEHUNTER also uses an improvement to a previously described algorithm to perform complete multipoint linkage analysis with a large number of highly polymorphic markers in pedigrees of moderate size (Kruglyak *et al.*, Am. J. Hum. Genet., 58:1347 [1996]). Due to computational constraints, the three largest pedigrees were each split into two parts.

Only one marker, D15S1360, yielded a lod score >3.0 (lod score maximum = 5.3, $\theta = 0.0$, $P < 0.001$). DNA markers flanking D15S1360 also gave positive lod scores. Multipoint analysis showed a maximum lod score at D15S1360 of 5.29. Both the sibpair analysis and nonparametric linkage analysis gave confirming positive results of similar statistical significance. The sibpair analysis showed 0.70 proportion of D15S1360 alleles among siblings with abnormal P50 ratios ($T = 4.07$, $P < 0.0005$). Two point results from the non-parametric analysis were most significant for D15S1360 ($Z = 3.95$, $P < 0.0002$). A complete multipoint analysis using nine chromosome 15q markers gave a maximum value at D15S1360 ($Z = 5.04$, $P < 0.000016$).

From the above it should be clear that the present invention provides gene sequences encoding mammalian $\alpha 7$ genes and proteins. The present invention further provides compositions and methods for targeted therapy directed to $\alpha 7$ abnormalities.

All publications and patents mentioned in the above specification are herein incorporated by reference. Various modifications and variations of the described method and system of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in molecular biology or related fields are intended to be within the scope of the following claims.